A STUDY OF SOME RESPONSES OF FLORIDA CITRUS TREES TO NITROGEN NUTRITION AND IRRIGATION

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By

AHMED MOHAMED LABIB EL-TOMI

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I. INTRODUCTION

In plant nutrition, nitrogen is of vital importance to the plant as it is one of the most important of the major plant nutrients required for protoplasm building.

The well-drained sandy soils of Florida are characterized by a low nitrogen content because of the rapid oxidation of the soil organic matter and lack of sufficient clay to hold the plant nutrients against the heavy rainfall. Consequently, nitrogen application has been a constand need in most Florida citrus soils (133).

The abundant rainfall, which depletes the plant nutrients as fast as they accumulate in the well-aerated soils used for citrus, is not very well distributed during the year and irrigation has been a controversial problem.

Nitrogen requirements of a plant have been determined through methods of application, such as to the soil, in nutrient cultures, or in foliar sprays, but "the field method has been the ultimate test to which the findings of any other proposed method must be submitted" (57).

Many research workers have tackled the nitrogen problem from the crop angle. Recently, the evidence available suggests very strongly that it should be quite possible, by means of plant analysis, to predict the main fertilizer requirements of any plant, no matter what the soil and climatic conditions may be (7). Meanwhile, few investigators have

studied the nitrogen problem from the standpoint of the response of the citrus tree to different levels of nitrogen applications under different levels of soil moisture.

In order to determine the response of the citrus tree to the above factors, several measurements have been selected in this study, to bring out the required information concerning the nitrogen status in the citrus leaf and its chlorophyll content. Moreover, a study of the possible effect of these factors on fruit splitting was also undertaken.

Two citrus species, on two different rootstocks, were selected to evaluate the response of inheritance to such a wide variability of environmental conditions, in two successive years.

II. REVIEW OF THE LITERATURE

1. The nitrogen status in the citrus leaf: It is evident that plants grown in cultures can make equally normal growth in a wide range of culture solutions (71). Working on citrus nutrition, Chapman and Liebig (26) found that a sweet orange seedling can reach a rapid rate of development if it grows in a well aerated water culture in a wide range of nitrate concentrations. When the leaves were analyzed for the nitrogen per cent on a dry weight basis, the limit values were 2.05 and 3.69 per cent, corresponding to concentrations of 0.67 and 68.8 ppm of nitrates in the solution, respectively.

Studies on nitrogen nutrition of cotton (121) and wheat (13) supported the conclusions of Chapman and Liebig. Magistad and Breazeale (82), working with several plants, reached similar results. However, they found that both potassium and phosphorus salts were absorbed differently.

Periodicity of nitrate absorption has been observed by several investigators. Chapman and Parker (27), studying weekly absorption of nitrates by young Valencia orange trees in solution cultures, found the least absorption was in January and February, when the solution and the air temperature were at a minimum, while the period of greatest absorption was in summer and fall when the maximum solution and air temperatures existed. Furthermore periods of intense nitrate

absorption were associated with periods of either active root growth or active bloom and foliage growth. In a similar experiment, Roy and Gardner (102), working with Parson Brown oranges budded on rough lemon, observed that nitrogen was absorbed at all seasons of the year with the highest rate in April and May, and the lowest rate in January and February. In a similar line of investigation, Wallace (125), working with Eureka lemon cuttings, found that a substantial amount of nitrogen was absorbed at 48° F., while at 74° F. nitrogen absorption reached the maximum, and it decreased definitely at 90° F.

Testing the tissues of plants grown under field trials has been a guide to the soil's available nutrients. Studies of Work (132) on the fertilization of barley, oats, peas, and wheat, using three levels of sulphate of ammonia, together with those of Proebsting on figs (99), indicated that the nitrate nitrogen tended to be highest in plants from the plots that had received the heaviest dressing of nitrogenous fertilizer. Ulrich (116), reached similar results from his determinations of nitrate content of the grape leaf petioles. However, leaf blade results failed to correlate with the nitrogen application rate. A positive correlation between the soil nitrogen level and the nitrogen levels in the leaves, expressed as percentage of dry weight, was found with the sugar cane (134), Elberta peaches (66), and with Stayman (126), and McIntosh apples (11). However, Borden (10), working with sugar cane in a similar research, found that the total nitrogen content of dry

weight reflected the response of the plants to the nitrogen application levels better than the nitrogen percentage of dry weight. Several workers, studying apples (26), peaches (66) and figs (99), have all reported a decrease in nitrogen content of leaves as the season progressed under all soil nitrogen treatments.

In the citrus field similar investigations have been carried out. Martin (84), working on physiological studies of Marsh grapefruit, disclosed that trees which received continuous nitrogen applications in winter, spring, and summer maintained the highest percentage of nitrogen in their leaves, while those picked from no-nitrogen plots had a marked deficiency in nitrogen. However, every treatment had a slight decrease in leaf nitrogen level, whether expressed as percentage or as total nitrogen content, between February and March samplings. Very young leaves, taken in late March or early April, may contain as much as 5 per cent nitrogen on a dry weight basis. The seasonal changes of nitrogen levels in all the treatments were characterized by a slight decrease throughout the spring, summer, and fall, followed by a rapid decrease in late winter. Responses of Marsh grapefruit trees to fertilization, reported by Finch and McGeorge (45), indicated that different forms of mineral nitrogen carriers, being added in equivalent amounts, gave the same responses; but trees receiving 1 and 2 pounds of nitrogen showed no differences in their yields or in their leaf nitrogen expressed as per cent of dry weight. However, Van der

Merwe's (117) studies with young Washington navel and Valencia oranges on rough lemon rootstock grown in sandy cultures indicated that the trees which received nitrogen entirely or predominantly in the ammonium form had a much higher nitrogen content than those receiving their nitrogen entirely in the nitrate form. The influence of age of Valencia leaves on their composition was revealed by Cameron et al. (22) in their study, which indicated that the nitrogen percentage of Valencia leaves varied within flushes, between flushes, and between years. Reasons responsible for such a wide variability are mostly the relative number of new leaves in each flush, blossoming and fruiting efficiency of the tree, and its tendency to alternate bearing. Furthermore, studies of Smith et al. (107) showed a direct relationship between the nitrogen level received by the tree and both its leaf nitrogen per cent and the dry matter concentration in the various tree fractions. Further evidence concerning the relationship mentioned above was furnished by Chen's (28) studies on the absorption of nitrogen by citrus from foliar applications of urea. Meanwhile, Smith and Reuther (105) have furnished evidence concerning the differing efficiencies of different rootstocks in nitrogen absorption.

The nature of the nitrogen curve, over a period of time, in a plant has been demonstrated in many plant analyses. Cook (34), working on fertilization of small grains, noticed that the total nitrogen in a tissue, regardless of fertilizer treatment, declined steadily throughout

the growing season. In a study of the distribution of total nitrogen in the orange tree, Cameron and Appleman (18) found that nitrogen had been accumulated in the leaves during late summer and autumn, which would probably help in blossom development in March and April.

A study of the effect of the season of nitrogen application on nitrogen level of old and new leaves of grapefruit trees by Hilgeman (69) indicated that August fertilization induced a high nitrogen level in old leaves during the fall and winter, but did not have this effect on the new leaves, while December application increased the nitrogen level in both. Spring application, in February, induced a high nitrogen level in the new leaves while the old ones remained unaffected. However, a decrease in nitrogen was found to occur in all parts during active growth periods in the spring and early summer. Later, during summer and autumn of each year, a gradual increase in nitrogen occurred and reached its maximum in mid-winter. In a similar study, Winston and Parker (129), working on Washington navel orange trees under five levels of fertilization, found a general decline in nitrogen, phosphorus, and potassium content of the leaf with age. Meanwhile, both P_2O_5 and K_2O, applied at different rates, had no effect on the accumulation of nitrogen, which reached a maximum of 2.88 per cent in September and a minimum of 2.00 per cent in the old leaves in April. In another paper, these authors (130) confirmed their previous conclusions with the Valencia orange. However, Smith and Reuther (106)

working on the seasonal changes in Valencia trees, found that the very young leaves were rich in nitrogen. A gradual decrease in nitrogen per cent took place between March and June, and then the nitrogen content remained nearly constant until February, followed by another decrease towards the end of the life cycle of the leaves. They showed also that the fluctuations in the percentage of nitrogen were related to both the application of fertilizer and the growth activities of the trees.

The effect of nitrogen applications in inducing more dry weight per plant has been known for a long time. Fraps (47), working on several crops grown under several levels of nutrients in a pot experiment, disclosed a correlation between the weight of the crops and the increase in the nitrogen content of the culture solution up to 600 ppm. Further studies on apple nutrition by Frear and Anthony (48) gave additional evidence as to the relationship between the dry weight and the nitrogen application. However, the first samples taken in each year failed to show any significant difference between the treatments. Meanwhile, a study on apple fertilization carried out by Verner (118) showed that most of the nitrates received by the plant were used in increasing leaf areas rather than adding more nitrogen to the fruits. Recent studies on rubber plant nutrition showed a positive correlation between the nitrogen per cent of dry leaves and the $\log_{10}$ of the fresh weight of seedling leaves (24).

Nutritional studies on Valencia orange by Reuther and Smith

(100) indicated that heavy nitrogen fertilization produced only a slight increase in tree growth. However, in a more recent study these authors found that the dry matter concentration in the various tree fractions of the Valencia orange tree grown in a sandy culture was directly related to the nitrogen level (107).

The effect of leaf nitrogen level on its dry weight percentage has been a new field in research. In a study on the nitrogen nutrition of tobacco, Garner et al. (53) found that an increased supply of nitrogen was associated with an increase in the water content of the leaf together with a decrease in dry weight per unit area of the leaf. However, such leaves were characterized by an increase in area compared to leaves taken from plants which had received lower nitrogen applications. In a similar line of investigation, Das (36), working on nitrogen nutrition of sugar-cane, found that nitrogen promoted succulence in canes, which was correlated with more water per gram of dry matter. However, the hydration of the tissue varied not only with the treatment but also with the season, and to a much greater extent. Furthermore, the medium nitrogen application generally produced a much greater amount of dry matter than either the low or the high nitrogen applications, which were closely alike in their effects. Working on young Valencia orange trees, Smith et al. (107), found that the highest rate of nitrogen application resulted in an increase in the dry matter percentage of all tissues.

Trees have often given no growth response to differential supplies of nitrogen when they were subjected to a new experiment for a short time, because they were still influenced by the previous treatment. In a set of long-term pot cultures of grapevines under different manurial treatments, Wagner et al. (132) observed that leaf analysis showed the tree response to the fertilizers better than any other tissue used. However, plants with leaves of more than 1.56% nitrogen, on a dry weight basis, showed no response to the fertilizer treatment. Studies on Marsh grapefruit by Hilgeman et al. (70) indicated that trees with nitrogen level as low as 1.7 per cent in their leaves prior to fertilization, reflected the tree response to the nitrogen application within about fifteen days; but trees with a high level of nitrogen in their leaves showed no response to the treatment. Similar results were brought forward by Martin (83) in his studies of the effects of cultural practices upon tree composition, yeild, and quality of Marsh grapefruit. Further studies on Marsh grapefruit by Winston et al. (128) indicated the existence of a negative correlation between the plane of nitrogen nutrition of the tree and the uptake of nitrogen from the soil.

2. Chlorophyll content: In a study of nitrogen of tobacco, Garner et al. (53) found that leaves suffering nitrogen deficiency, with pale yellowish-green color, had characteristic nitrogen contents of 1.5 per cent or below. Working on chlorosis of orange leaves, Parbery (94) reported that normal leaves had a significantly greater content

of magnesium and nitrogen than those of chlorotic nature.

The relationship between chlorophyll content of the rye plant and its nitrogen requirements was studied by Cassner and Goeze (54), who grew plants in pots of soil and of sand with different nitrogen levels. They noticed a diminution in the chlorophyll content whenever a plant had nitrogen deficiency and suggested the possibility of determining the nitrogen requirements of plants through determining their chlorophyll content.

Working on apple trees, Hamilton et al. (64) observed that urea sprays induced a deeper green color of the leaves. Further studies on nitrogen fertilization of McIntosh apples by Fisher and Cook (46), indicated that urea sprays increased both the nitrogen level and the chlorophyll content of treated leaves above that in the controls. Following the same line of investigation, Proebsting (98) noted a marked deepening in the green color of apple leaves following urea spraying. However, the stone fruits failed to give such a response.

In a study of the seasonal trends of both total nitrogen and chlorophyll content of Elberta peach leaves, Harris and Boynton (66) found that both the total nitrogen, expressed as per cent of dry weight, and the chlorophyll content were affected by the differential fertilizer and cultural treatments. Moreover, there was a significant correlation between the chlorophyll content of the leaf and its nitrogen percentage. Further observations revealed, however, that the chlorophyll content

of the leaf was affected by factors other than its nitrogen level.

Studies on the absorption of nitrogen by citrus trees from foliar applications of urea by Chen (28) supported the conclusions of Harris and Boynton concerning the relationship between chlorophyll content of leaves and their nitrogen level. Further studies on chlorophyll decomposition by Michael (85) furnished evidence that decreasing nitrogen content of old leaves is correlated with breakdown of chlorophyll.

3. Relation of soil moisture to tree growth and functioning: Water loss from fruit trees has long been a popular subject for investigation. Livingston and Brown (78) revealed that plant leaves, whenever they were subjected to relatively great diurnal evaporation intensity, might exhibit a marked fall in foliar moisture by day and a corresponding recovery by night. Furr and Magness (50) observed that apple trees can function efficiently as long as the soil moisture was above the wilting point. Otherwise, the trees adjust themselves through earlier closing of the stomata. Obviously, trees with limited and concentrated root systems will be the first to suffer during periods of poor moisture supply.

Compton (32), using the relative saturation deficit as an index to soil moisture values to determine the responses of navel orange trees to frequent and infrequent irrigations, found little difference between the two treatments in both leaf and fruit measures. A

maximum value of R. S. D. was reached between 12:00 noon and 2:00 P. M., while its minimum value was attained about 4:00 A. M. He considered that three factors were of prime importance in affecting the water deficit in citrus: high air temperature, lack of available soil moisture, and strong wind. However, when soil moisture was available, high temperature induced no appreciable differences in the value of R. S. D.

Studies on moisture absorption by tomato plants from an atmosphere of high humidity by Breazeale et al. (12) revealed the ability of leaves to absorb water from a saturated atmosphere and to build up a high turgor pressure in the plant; furthermore, in cases of extreme differences of moisture contents between the soil and the atmosphere, tomato leaves absorbed sufficient water to enable the roots to excrete water so that the soil around them reached field capacity or higher. However, such exuded water contained nutrient ions from the roots.

4. Shedding, dropping, and splitting of fruits: Studying the factors influencing the abscission of flowers and fruitlets of apples, Heinicke (67) mentioned that 40 to 80% of the flowers were lost in the first wave, and only from 3 to 7% of the total number of flowers developed into fruits. He suggested that available water supply in soil, in addition to an application of a quick-acting nitrogenous fertilizer early in the spring, might help in increasing fruit set.

In a study of the abnormal water relations in citrus trees,

Hodgson (73) noticed that diurnal decrease in water content of the fruits occurred during the afternoon, associated with a considerable increase in the water deficit of the leaves. Such conditions build a negative pressure in the water columns of the tree sufficient to induce dropping in severe waves, mainly when the water relations were abnormal. Further investigation on the abnormal shedding of young navel orange fruits, carried out by Coit and Hodgson (29), showed that shedding was due to a stimulus to abscission which arose from daily water deficits in the developing fruits, in addition to the high soil temperature during the summer time which was enough to inhibit water absorption by the plant at the very time of day that water was required most. In order to reduce those waves of shedding, they suggested heavier and more frequent irrigation, planting of intercrops to shade the soil, mulching with straw, protection by windbreaks, and a reduction in the leaf area through moderate winter pruning.

From South Africa, Wager (122) reported the absence of any difference between the fertilized navel orange trees and their controls either in the amount of drop, or in the time at which it took place. Moreover, he noticed that shedding and dropping of fruits could be correlated with weather conditions such as high temperature, low humidity, and strong wind.

Working on Marsh grapefruit, Martin (84) observed that trees receiving no nitrogen had less than 1,400 blossoms per tree, which

was much less than in any other nitrogen treatment. Moreover, the fruit set on no-nitrogen trees was around 0.80% while it was 4.97% and 5.40% respectively, in winter-nitrogen and winter-starved plots.

Under Florida conditions, splitting has been a serious problem. O'Byrne (90) mentioned that it exists every year about the first of September, mainly in Valencia oranges.

Studies by Furr et al. (51) on drop of young navel orange fruits and the influence of spring moisture on it, revealed that the availability of water supply affected leaf growth but not fruit set. Moreover, trees supplied with 2.3 and 3.1 pounds of calcium nitrate per tree, in addition to ample soil moisture supply maintained from May to July, showed even greater variation in number of fruit set than did the trees in dry and wet treatments. They also noted that high temperature was an important factor in causing abnormally heavy drop of fruit, due to building up of a severe water deficit in the fruit by hot, dry weather.

Working on dropping of apples, Southwick (109) reported that a high state of fertility, especially in regard to nitrogen, tends to increase pre-harvest dropping of the McIntosh variety. Dickson (39) noted that minimum cultivation to reduce the amount of nitrates in the soil, mainly in midseason, reduced the percentage of McIntosh drops.

III. MATERIALS AND METHODS

1. Materials: For studying the response of the citrus tree to different levels of nitrogen nutrition under different conditions of soil moisture in the field, two different species on two different rootstocks were selected--the Hamlin sweet orange (Citrus sinensis Osbeck) on sour orange stock and the Owari satsuma (Citrus reticulata Blanco) on trifoliate stock.

The trees were spaced 20 x 20 feet in the old citrus grove in a well drained soil of Gainesville type and they were in a very good condition. In March, 1952, when the experiment started, the Hamlins were 31 years of age and the satsumas 7 years old. Eighteen Hamlin trees and 24 satsuma trees were selected at random. In both cases, six trees constituted a block to receive all the treatments of the experiment.

2. Treatments: Six treatments were selected and arranged in a factorial combination of two levels of irrigation--the field capacity treatment and the unirrigated control--together with three levels of nitrogen--low, medium, and high.

In the field capacity treatment, the soil was kept close to field capacity by bringing the moisture content up to or above this point once each week by addition of 2.3 inches of water by sprinkler irrigation. While the soil was not actually at field capacity constantly, it never fell far below this point and was always far above the wilting percentage.

In case of rain, its total in a week period would be subtracted from 2. 3 inches and the remainder, if positive, would be added. The trees under control treatments received no water except by rainfall.

Trees kept on a low nitrogen level received no nitrogen application. A half pound of sodium nitrate per box per tree was applied to the trees in the medium level treatment; while a full pound of that fertilizer, per box per tree, was added to those on the high nitrogen level. These amounts were applied three times a year and in two successive seasons. The first application was in March, while the second and the third ones were in June and November, respectively. In addition, 2 pounds of the mixture of 0-6-8-3-1, * per box per tree, were applied to all the trees of the experiment indifferently. Each treatment was replicated three times in the Hamlins and four times in the satsumas, in a randomized block design.

3. Selected measurements: In order to study the responses of the trees to the six treatments mentioned previously, eleven measurements were selected to be studied in both species for two seasons. These were: (1) total fresh weight of leaves per sample, (2) total dry weight of leaves per sample, (3) the dry weight percentage of leaves, (4) number of leaves per sample, (5) the weight of a certain leaf area, (6) average dry weight per leaf, (7) chlorophyll content of leaves,

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*N-P_2O_5-K_2O-MgO-MnO

TABLE 1

Amounts of Rainfall Received by the Citrus Grove in Two Seasons in Inches per Month

Month	Season 1952-1953	Season 1953-1954
March	2.33	3.87
April	3.20	8.43
May	4.44	2.29
June	3.31	12.35
July	3.85	6.71
August	3.99	12.78
September	4.66	5.58
October	4.73	3.37
November	0.88	2.67
December	2.39	9.00
January	4.60	1.16
February	1.05	1.73
TOTAL	39.43	69.94

(8) per cent nitrogen of leaves on dry weight basis, (9) total nitrogen per sample, (10) total nitrogen per leaf, and (11) the rate of flower shedding, fruit dropping, and splitting. The first ten measurements were assigned to be sampled at monthly periods while measurement of the rate of shedding, dropping, and splitting was assigned to be sampled weekly.

4. Sampling: In the spring, in each season, 70 non-fruiting twigs from the new spring flush of the Hamlin trees, and 50 similar ones of satsuma, were selected and tagged around the periphery of each tree in the experiment, They were selected from a zone of 3 to 6 feet above the ground. Those selected twigs were assigned for the monthly samplings throughout the season of twelve months (106).

At monthly periods, four of these twigs of nearly equal distribution around the periphery of each Hamlin tree and three similar twigs of satsuma were removed. In each sampling case, the twigs of each tree were composited to form one tree sample from which the information concerning the first ten measurements, for that particular date of sampling, was obtained.

In each sample, the twigs were thoroughly washed with tap water, and their leaves were separated with a pair of scissors and immersed in distilled water for a while, then dried with a cloth. The total weight of all the leaves of each sample was recorded as total fresh weight of leaves, and the number of leaves in each sample was

also recorded. For determining the total dry weight of leaves, the sample was dried over night in an electric oven at 70° C.

The dry material was ground in an automatic Wiley mill to a fineness of 60 mesh. The ground material of each sample was received in a clean, dry glass container labeled with the tree number, variety, and date. Each container was then covered with a tight screw cap, ready for the subsequent nitrogen analysis.

For chlorophyll sampling, thirty disks of 16.6 mm. diameter were selected at random and placed in 30-40 ml. of methanol in a wide-mouth colored glass jar after determining their fresh weight. The jars were labeled with the tree numbers and were tightly covered with screw caps for the subsequent chlorophyll determination.

For sampling the rate of flower shedding and fruit dropping, an area of one square yard was laid out, underneath the canopy of the tree on the western side, to receive the flowers and the fruitlets. Those were counted and recorded at weekly intervals. For measuring splitting, the whole ground area under each tree was used and the split fruit found underneath the area were counted and recorded at weekly periods.

5. Analytical Methods: The procedure used for per cent nitrogen determination, on a dry weight basis, was mainly the one described in A. O. A. C. methods (1) with some modifications. Around 30 mg. of the ground dried material was folded in a piece of cigarette

paper of known weight, weighed to the nearest 0.1 mg., and transferred to a clean semi-micro 30 ml. Kjeldahl flask. Two grains of carborundum, 2 ml. of concentrated H_2SO_4, and a small pinch of sodium thiosulfate were then added to the flask. For a period of 10 minutes the flask was left on the digestion rack before it was subjected to a gentle heat for 5 minutes. After cooling, 1.34 gm. of a mixture of 1 gm. $CuSO_4$ with 50 gm. K_2SO_4 was added and the flask was swirled several times during the subsequent gentle heating. When the fumes of sulfur trioxide were no longer evolved, the flame was increased gradually until the whole material was completely digested. After the liquid became colorless, the flask was left to cool, and then about 5 ml. of distilled water was added and the flask was rotated vigorously after a thin film of vaseline was placed on its lip.

To a 125 ml. Erlenmeyer flask, 5 ml. of 4% H_3BO_3 solution and two drops of methyl red-methylene blue indicator were added. After steam had been passed through the condenser for 15 minutes, the Erlenmeyer flask was placed under the condenser, with the tip extending below the liquid surface, and the digest was then transferred to the distillation apparatus with several small washings followed by 10 ml. of 40% NaOH. After closing the stopcocks, the flame was put under the steam generator and in about ten minutes the whole NH_3 distillation would be over. The flask would contain by that time about 50 ml. of condensate.

The titration of the liquid in the receiving flask was carried out with 0.02 N HCl, measured by a burette graduated to the nearest 0.02 ml. Each sample was run in duplicate together with a blank for each series. The per cent N in the sample was calculated by the following equation:

$$N\% = \frac{(\text{ml. HCl; determination} - \text{blank})(\text{normality})(0.014)(100)}{\text{dry weight of sample in mg.}}$$

The values of the duplicates were averaged if they were within 5% deviation from their averages. Otherwise, a new determination for that sample was made following the same procedure. Those averages represented the per cent nitrogen, on a dry weight basis, at that particular date for the given tree.

For total chlorophyll determination of leaves, the method first suggested by Compton and Boynton (33) with modifications by Gross (60) was used. The thirty disks which were previously mentioned under "Sampling" were stored in the dark in methanol for 24 hours or more, and then comminuted in a Waring Blendor for 5 minutes. The whole composite was poured into a beaker and several washings with small amounts of methanol were used to transfer the whole extract with the pulp from the jar. The composite was filtered through an 11 cm. Schleicher and Shull #595 filter paper into a 100 ml. volumetric flask and the filtrate was made up to volume through washing the residue with several additional portions of methanol. The total chlorophyll

of the thirty disks was calculated from the percentage transmittance through a red filter of 650 millimicron wave length in a Fisher Electrophotometer previously calibrated for chlorophyll (1).

6. Expression of results: The dry weight percentage of leaves was obtained by dividing the total dry weight of leaves by their total fresh weight and multiplying the fraction by one hundred. Average leaf dry weight of a tree at any time was determined by dividing the total dry weight of the leaves, at the time, by the number of leaves in that sample.

The total nitrogen per sample was obtained by multiplying the total dry weight of the sample by its per cent N. However, the total nitrogen per leaf was obtained through dividing the total nitrogen per sample by its number of leaves.

7. Presentation of data and the statistical analysis: Each measurement, of the first ten, was recorded at monthly periods for both Hamlins and satsumas. The original data, with the records of all replications in every treatment, were analyzed statistically by means of the analysis of variance (108). However, the tables in the text are the averages for each treatment.

IV. RESULTS

1. Fresh weight of leaves per sample: Data on fresh weight of leaves of Hamlin orange and (Owari) satsumas are presented in Tables 2, 3, 4, and 5. A summary of the analysis of variance for these data is given in Table 1a in the Appendix.

It is evident that Hamlins and satsumas did not respond alike to the treatments, and that neither made the same response in one season as in the other. During the first season, neither variety showed significant response to the treatments used. With both varieties, however, the average fresh weights were highest in the autumn. The mean fresh weight of the leaves on satsuma twigs was consistently greater than that of the leaves of Hamlin twigs.

During the second season, both varieties showed significant response to the treatments used. Low nitrogen treatments, with irrigation and without it, gave significantly lower responses than the treatments of both medium and high nitrogen levels. This response to nitrogen was significant at the 5 per cent level in the Hamlins, but at the 1 per cent level in the satsumas. Meanwhile, irrigation caused no response in either fruit. Furthermore, there was no real difference between the medium and the high nitrogen levels as far as their responses in either variety are concerned. With all the treatments, the fresh weight of satsuma leaves showed an increasing trend throughout

TABLE 2

Mean Fresh Weight in Grams of Leaves of Three Twigs of Satsumas as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	28.00	30.41	24.75	33.68	26.40	27.93	28.53
July	31.27	25.13	31.33	33.41	27.85	28.96	29.66
August	29.75	31.82	28.97	32.65	29.31	33.07	30.93
September	30.03	34.71	33.05	37.33	26.79	39.03	33.49
October	34.87	33.88	26.60	34.32	32.78	35.98	33.07
November	30.89	35.09	27.39	36.46	32.21	30.44	32.08
December	33.54	30.90	33.81	34.39	31.90	36.80	33.56
January	20.61	26.86	23.43	26.06	24.24	24.03	24.21
February	20.81	25.90	30.14	27.63	31.94	31.99	28.07
Average for Treatments	28.86	30.52	28.83	32.88	29.27	32.03	

No significant difference between treatment averages.

TABLE 3

Mean Fresh Weight in Grams of Leaves of Four Hamlin Twigs as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	15.24	16.00	17.22	17.43	19.83	19.06	17.46
July	18.76	18.80	19.11	18.77	20.37	26.76	20.43
August	17.25	20.92	21.64	21.64	20.92	23.42	20.97
September	21.54	19.97	21.22	24.36	20.01	20.81	21.32
October	19.24	19.62	24.82	19.64	20.22	23.25	21.13
November	14.18	18.04	19.56	20.44	19.04	16.17	17.91
December	18.65	20.20	17.41	19.53	17.42	20.69	18.98
January	20.69	21.40	21.22	23.15	20.72	17.65	20.81
February	17.75	15.69	14.01	19.37	19.02	15.36	16.87
Average for Treatments	18.14	18.96	19.58	20.48	19.73	20.35	

No significant difference between treatment averages.

TABLE 4

Mean Fresh Weight in Grams of Leaves of Three Satsuma Twigs as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	12.17	10.85	14.31	15.01	15.75	18.27	14.39
April	14.42	15.75	20.22	17.44	20.15	23.25	18.54
May	19.00	23.60	20.08	18.10	19.45	22.35	20.43
June	13.31	19.39	20.59	11.54	19.32	17.20	16.89
July	10.76	21.50	21.26	13.86	20.63	24.17	18.70
August	20.36	19.24	21.89	17.25	23.88	21.72	20.72
September	13.01	21.16	26.52	15.84	23.17	22.02	20.29
October	14.86	21.03	19.32	15.22	16.77	17.38	17.43
November	14.38	29.65	20.08	15.08	17.56	22.66	18.24
December	11.34	20.40	18.88	11.53	14.91	18.79	15.98
January	11.45	21.66	19.00	12.60	15.01	20.73	16.74
February	15.54	25.63	21.45	16.78	21.50	23.90	20.80
Average for Treatments	14.22	19.99	20.30	15.02	19.01	21.04	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means[1]:	2.93 gms.	4.07 gms.
Nitrogen Means[1]:	2.08 gms.	2.88 gms.

[1]In this table and subsequent tables the L. S. D. for teatment means is applicable to the given array of means while the L. S. D. for either nitrogen or irrigation means are applicable to the average of nitrogen or irrigation means, respectively.

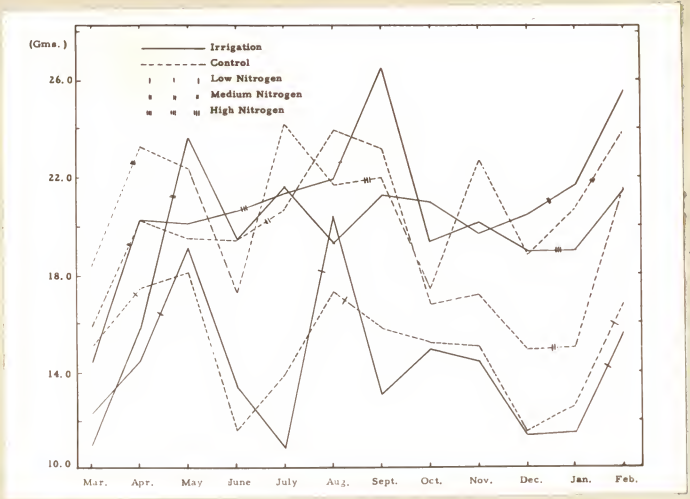


Figure 1. Mean fresh weight in grams of leaves of three twigs of satsuma during the 1953-1954 season.

TABLE 5

Mean Fresh Weight in Grams of Leaves of Four Hamlin Twigs as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	15.35	12.90	13.75	12.63	12.74	12.08	13.24
April	10.94	10.43	10.70	10.42	11.80	10.35	10.77
May	11.00	10.09	10.54	10.79	10.61	9.31	10.39
June	12.01	10.95	13.49	8.53	10.24	10.36	10.93
July	8.23	11.87	11.71	8.56	11.57	11.05	10.50
August	7.57	11.07	11.03	8.13	9.87	10.29	9.66
September	8.85	11.64	12.97	10.53	9.84	10.41	10.71
October	9.98	10.96	11.05	11.25	12.44	12.33	11.34
November	10.75	10.49	12.20	10.34	14.32	11.41	11.59
December	9.62	10.23	12.52	7.79	10.54	10.07	10.13
January	8.08	9.76	11.63	11.00	9.58	11.55	10.27
February	8.54	13.31	11.64	9.36	12.18	14.38	11.57
Average for Treatments	10.08	11.14	11.93	9.94	11.31	11.13	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	1.64 gms.	2.34 gms.
Nitrogen Means:	1.16 gms.	1.65 gms.

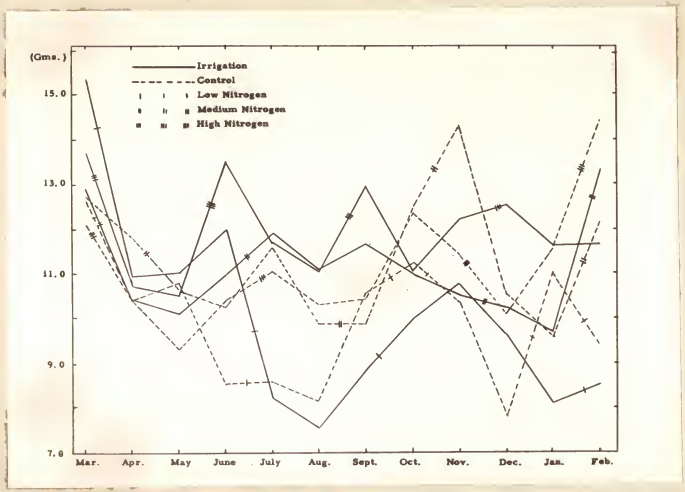


Figure 2. Mean fresh weight in grams of leaves of four twigs of Hamlins during the 1953-1954 season.

the season, with a maximum average weight at the end of the season in February, while a minimum average weight occurred at the beginning of the season in March. The seasonal fluctuations of the fresh weights of leaves of the Hamlin orange showed a maximum average in March and a minimum average in August, quite unlike the seasonal pattern of the satsumas, as shown in Figures 1 and 2. Furthermore, the values for fresh weights of leaves under various treatments in both varieties maintained the same relative positions throughout the season. However, a pooled analysis of data for both varieties during the second season, presented in Table 2a of the Appendix, revealed that Hamlins and satsumas are different in their responses to the different treatments as far as the fresh weight of leaves is concerned.

A study of the relationship between the relative mean fresh weights of leaves as determined by the differential nitrogen levels is presented in graphic form in Figure 3. Evaluation of their curvilinear regression correlation indicated the presence of a highly significant correlation in satsumas while that of Hamlins was significant only at the 5 per cent level.

2. Dry weight of leaves per sample: Results of determination of dry weight of leaves, of both varieties, are set forth in Tables 6, 7, 8, and 9. A summary of the analysis of variance for these data is given in Table 3a of the Appendix.

It is apparent that neither variety showed significant response

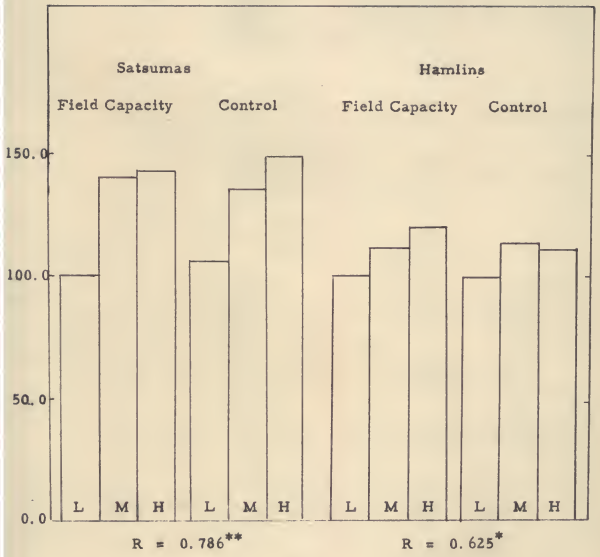


Figure 3. The relationship between nitrogen levels and the seasonal averages for fresh weight of leaves per sample, 1953-1954 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen

TABLE 6

Mean Dry Weight in Grams of Leaves from Three Twigs of Satsumas as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	9.11	10.88	8.60	11.81	9.82	9.37	9.93
July	11.17	8.82	10.62	12.00	9.00	10.13	10.42
August	9.78	10.92	9.80	11.06	9.90	10.93	10.40
September	10.04	12.10	11.17	12.78	8.99	13.16	11.37
October	12.81	12.44	9.55	13.13	12.32	12.54	12.13
November	12.15	13.84	10.59	14.25	13.58	11.26	12.61
December	12.91	11.40	12.16	13.41	11.76	13.74	12.73
January	8.55	11.20	9.75	12.02	10.57	11.61	10.62
February	9.07	11.52	13.47	12.05	13.65	14.06	12.30
Average for Treatments	10.62	11.46	10.75	12.50	11.15	11.87	

No significant difference between treatment averages.

TABLE 7

Mean Dry Weight in Grams of Leaves from Four Hamlin Twigs as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
July	6.22	6.19	6.17	6.12	6.64	8.62	6.66
August	5.66	7.30	7.23	7.12	6.29	7.92	6.92
September	6.77	6.36	6.97	7.91	6.35	6.72	6.85
October	5.96	6.22	8.26	6.26	6.81	8.24	6.96
November	4.98	6.14	7.22	7.73	6.63	5.87	6.43
December	7.22	7.56	6.63	7.29	6.39	8.57	7.28
January	6.79	7.23	7.22	8.24	7.21	6.03	7.12
February	5.00	4.26	3.98	4.87	4.96	4.39	4.58
Average for Treatments	6.08	6.41	6.71	6.94	6.41	7.05	

No significant difference between treatment averages.

TABLE 8

Mean Dry Weight in Grams of Leaves from Three Satsuma Twigs as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	2.32	1.61	2.71	2.92	3.03	3.53	2.69
April	4.10	4.59	5.92	5.07	6.14	7.23	5.51
May	6.49	8.45	7.10	6.40	6.84	8.04	7.22
June	4.38	6.58	7.08	3.66	6.62	5.96	5.71
July	3.29	7.14	7.20	4.46	7.26	8.46	6.30
August	6.16	6.13	6.69	5.41	7.62	6.81	6.47
September	4.17	7.23	9.30	5.31	8.56	5.70	6.71
October	4.78	6.96	6.40	5.11	5.65	5.91	5.81
November	5.13	6.76	7.20	5.46	6.33	7.71	6.43
December	3.85	7.60	6.78	3.96	5.93	6.84	5.83
January	4.18	8.86	7.62	4.96	5.93	7.97	6.59
February	6.54	10.55	8.56	6.65	8.71	9.52	8.42
Average for Treatments	4.62	6.87	6.88	4.95	6.55	6.97	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	1.14 gms.	1.58 gms.
Nitrogen Means:	0.80 gms.	1.11 gms.

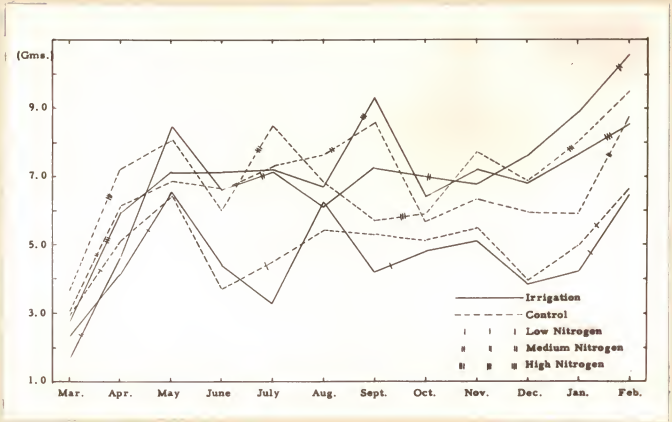


Figure 4. Mean dry weight in grams of leaves from three satsuma twigs as affected by varying soil moisture and nitrogen application levels during the 1953-1954 season.

TABLE 9

Mean Dry Weight in Grams of Leaves from Four Hamlin Twigs as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	3.63	2,92	3.15	2.94	2.88	2.81	3.06
April	2.94	2.91	3.01	3.05	3.21	2.95	3.01
May	3.18	3.13	3.10	3.29	3.17	2.81	3.11
June	3.59	3.23	4.27	2.46	3.11	3.16	3.30
July	2.43	3.78	3.85	2.59	3.71	3.49	3.31
August	2.21	3.44	3.56	2.29	3.02	3.01	2.92
September	2.39	3.42	3.83	3.10	2.71	3.00	3.08
October	2.98	3.55	3.72	3.64	4.00	3.90	3.63
November	3.51	3.58	4.32	3.43	4.85	3.90	3.93
December	3.28	3.41	4.53	2.52	3.50	3.31	3.43
January	2.32	2.94	3.59	3.39	2.77	3.50	3.09
February	2.78	4.62	3.97	3.19	4.71	5.01	4.05
Average for Treatments	2.94	3.41	3.74	2.99	3.47	3.40	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.60 gms.	0.85 gms.
Nitrogen Means:	0.42 gms.	0.60 gms.

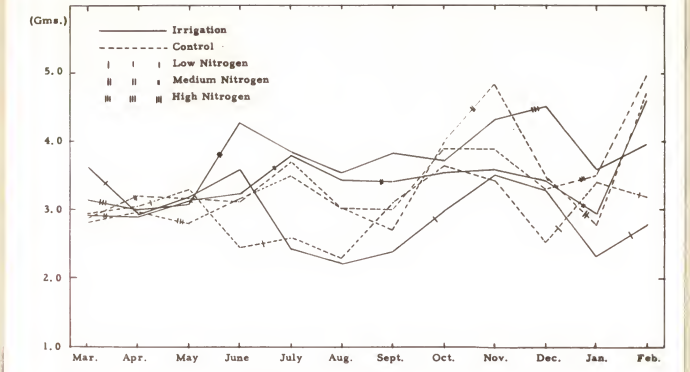


Figure 5. Mean dry weight in grams of leaves from four Hamlin twigs as affected by varying soil moisture and nitrogen application levels during the 1953-1954 season.

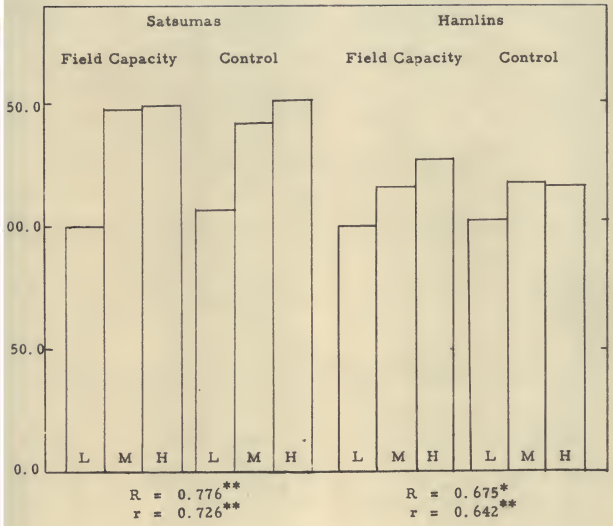


Figure 6. The relationship between nitrogen levels and the seasonal averages for dry weight of leaves per sample, 1953-1954 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen

to the differential treatments used during the first season. However, the mean dry weight of the leaves on a sample of 3 satsuma twigs was consistently greater than that of the leaves of the 4 Hamlin twigs composing a sample.

During the second season, significant differences in dry weight of leaves with different nitrogen application levels were obtained in both varieties. Low nitrogen treatments again gave significantly lower responses than either the medium and high nitrogen treatments, the differences being significant at the 5 per cent level in Hamlins and at the 1 per cent level in satsumas. Meanwhile, irrigation induced no response in either case. Differences in responses for medium and high nitrogen treatments are nonsignificant in either case. Seasonal fluctuations of both varieties are presented in graphic form in Figures 4 and 5 to demonstrate the two different patterns. While that of the satsumas is characterized by a minimum value of 2.69 grams in March and a maximum value of 8.42 grams in February, the Hamlins show little variation during the season. The values for dry weight of leaves under various treatments in both varieties maintained the same relative positions throughout the season. Furthermore, pooled analysis of data for both varieties, presented in Table 4a of the Appendix, gives further evidence that Hamlins and satsumas are different in their responses to the differential treatments, as far as the dry weight of leaves is concerned.

The relationship between the nitrogen application levels and the

relative mean dry weights of leaves, for both varieties, is demonstrated graphically in Figure 6. Evaluation of their regression correlation indicates that a highly significant correlation is present in both cases.

3. Dry weight as per cent of fresh weight: Results of determination of dry weight percentages of both Hamlins and satsumas are presented in Tables 10, 11, 12, and 13. Analysis of variance of these tables is summarized in Table 5a of the Appendix.

Evidently no significant response to the differential treatments was shown in either variety during the first season. However, the mean dry weight percentage of the leaves on satsuma twigs was consistently larger than that of the leaves of Hamlin twigs.

During the second season, irrigation gave no significant response in either variety, and Hamlin oranges showed no response to the nitrogen treatments used. Low nitrogen treatments gave significantly (1%) lower values of dry weight percentage in the satsuma than did either the medium and high nitrogen treatments, although differences between the medium and high nitrogen treatments means were not significant.

In Figure 8 are shown the seasonal fluctuations of dry weight percentage of satsuma leaves, increasing steadily from a minimum in March to a maximum in February. The graph of the Hamlin data presents a very similar picture seasonally, although the mean dry weight percentage of the leaves of Hamlins is consistently lower than that of

TABLE 10

Means of Dry Weight Percentages of Satsuma Leaves, per Three Twigs, as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	32.46	35.96	34.87	35.00	36.71	33.24	34.71
July	35.72	34.89	34.04	35.71	35.06	34.99	35.07
August	32.90	34.26	33.83	31.15	33.73	32.98	33.14
September	33.45	34.45	33.73	34.14	33.55	33.80	33.85
October	37.09	36.73	36.05	38.19	37.52	35.01	36.77
November	39.72	39.28	38.94	39.00	41.92	36.81	39.28
December	38.18	36.82	38.83	39.08	36.63	37.48	37.84
January	41.61	41.87	41.66	43.39	43.39	42.80	42.45
February	43.35	44.12	44.32	43.39	42.73	43.67	43.60
Average for Treatments	37.16	37.60	37.36	37.67	37.92	36.75	

No significant difference between treatment averages.

TABLE 11

Means of Dry Weight Percentages of Hamlin Leaves, per Four Twigs, as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
July	33.11	32.71	32.25	32.17	32.58	32.22	32.51
August	32.78	34.92	33.70	32.84	30.10	33.77	33.02
September	31.33	31.92	32.82	32.51	31.67	32.32	32.10
October	30.71	31.75	33.25	31.92	32.96	35.19	32.63
November	34.97	33.68	36.66	37.72	35.07	36.28	35.73
December	38.47	37.95	38.32	38.04	36.69	40.72	38.37
January	32.72	33.93	34.26	35.55	34.25	34.09	34.13
February	28.19	27.78	28.47	25.14	26.05	28.52	27.36
Average for Treatments	32.97	33.08	33.72	33.24	32.42	34.14	

No significant difference between treatment averages.

TABLE 12

Means of Dry Weight Percentages of Satsuma Leaves, per Three Twigs, as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	19.06	17.93	18.80	19.45	19.11	19.34	18.95
April	28.50	29.25	29.33	29.30	30.40	31.05	29.64
May	32.68	35.58	35.26	35.33	34.94	36.01	34.97
June	32.72	33.56	34.27	31.60	33.76	34.64	33.43
July	30.62	33.28	33.63	32.03	35.08	35.04	33.28
August	29.99	31.65	30.54	31.36	31.87	31.30	31.12
September	32.46	34.11	35.19	33.65	37.29	34.51	34.54
October	32.13	32.97	32.77	33.26	33.77	33.91	33.14
November	35.16	34.42	35.37	35.16	36.32	33.79	35.04
December	33.20	37.14	35.65	34.46	36.12	35.96	35.42
January	36.36	40.68	39.71	39.11	39.48	38.30	38.94
February	42.87	41.03	40.00	39.66	40.15	39.25	40.49
Average for Treatments	32.15	33.47	33.38	32.86	34.02	33.59	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	1.15%	1.60%
Nitrogen Means:	0.82%	1.13%

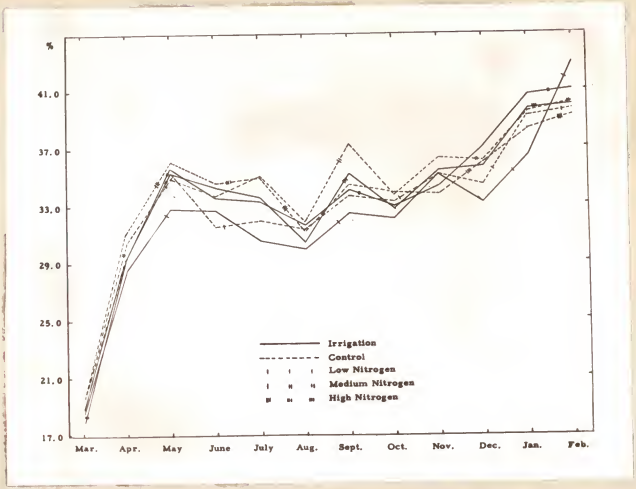


Figure 8. Means of dry weight percentages of satsuma leaves during the 1953-1954 season.

TABLE 13

Means of Dry Weight Percentages of Hamlin Leaves, per Four Twigs as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	23.33	22.46	22.88	23.26	22.39	23.19	22.92
April	26.72	27.83	28.02	29.25	27.27	28.39	27.91
May	28.94	30.61	29.45	30.30	29.86	30.24	29.90
June	29.96	29.77	31.62	28.63	30.43	30.51	30.15
July	29.50	31.84	32.67	30.10	31.80	31.62	31.26
August	29.21	31.02	32.14	28.04	30.50	29.32	30.04
September	26.78	29.35	29.55	29.05	27.48	28.82	28.51
October	29.82	32.61	33.74	32.34	32.65	31.65	32.14
November	32.85	33.55	35.30	32.98	33.85	34.14	33.78
December	34.07	33.00	36.05	32.34	33.18	32.64	33.55
January	28.63	30.11	30.80	29.70	28.82	30.28	29.72
February	32.52	34.75	34.01	33.62	38.71	34.97	34.76
Average for Treatments	29.36	30.58	31.35	29.97	30.58	30.48	

No significant difference between treatment averages.

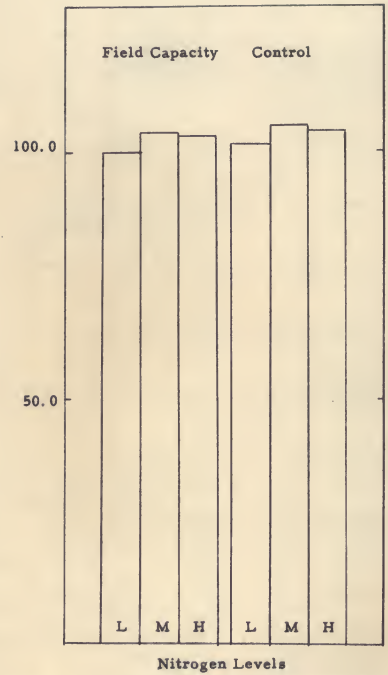


Figure 9. The relationship between nitrogen levels and seasonal averages for the dry weight percentage of satsuma leaves, 1953-1954 season.

L = Low nitrogen, M. = Medium nitrogen, H = High nitrogen

the satsuma leaves.

The relationship of differential nitrogen levels and the relative mean dry weight percentages of satsuma leaves is demonstrated graphically in Figure 9. Evaluation of its curvilinear regression correlation indicates that the correlation coefficient is significant at the 5 per cent level.

4. Number of leaves per sample: Results for both varieties during the two seasons are shown in Tables 14, 15, 16, and 17, while a summary of their analysis of variance is presented in Table 6a of the Appendix.

No significant response to the treatments used is noticeable from the first season data of either variety, but the mean number of leaves on three satsuma twigs was consistently larger than that of the leaves on four Hamlin twigs.

Second year data revealed a significant response to treatment, limited to Hamlin oranges. It is ascribed to the differential nitrogen levels and not to irrigation effect. Low nitrogen treatments produced significantly lower numbers than did the medium or the high nitrogen treatments, but there is no real difference in responses between the medium and the high nitrogen applications. The mean number of leaves on Hamlin twigs at monthly samplings, presented graphically in Figure 10, does not show any particular trend. Meanwhile, the relationship of the differential nitrogen levels to the mean number of Hamlin leaves,

TABLE 14

Mean Number of Leaves per Three Twigs of Satsumas as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	37	39	33	46	34	35	37
July	55	35	44	47	39	38	43
August	38	37	34	40	38	36	37
September	39	39	41	45	30	47	40
October	42	47	33	36	39	36	39
November	44	41	36	41	34	32	38
December	45	40	43	38	48	42	43
January	39	37	35	34	38	38	37
February	45	37	47	42	45	43	43
Average for Treatments	43	39	38	41	38	39	

No significant difference between treatment averages.

TABLE 15

Mean Number of Leaves per Four Twigs of Hamlins as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	28	23	31	28	25	28	27
July	27	32	33	31	29	36	31
August	31	28	35	30	30	33	31
September	34	26	35	38	26	29	31
October	26	27	36	26	28	28	29
November	22	24	28	27	25	25	25
December	30	32	30	28	22	34	29
January	30	34	35	31	26	26	30
February	37	35	37	39	44	37	38
Average for Treatments	29	29	33	31	28	31	

No significant difference between treatment averages.

TABLE 16

Mean Number of Leaves per Three Twigs of Satsumas as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	24	21	24	27	20	23	23
April	23	19	20	22	21	22	21
May	33	22	23	21	22	28	25
June	24	22	23	16	21	21	21
July	18	24	23	19	22	31	23
August	29	22	27	24	28	27	26
September	23	26	29	24	32	35	28
October	24	24	20	21	17	25	22
November	25	20	22	21	21	29	23
December	23	23	20	18	21	24	22
January	24	30	22	15	19	23	22
February	22	26	20	21	23	27	23
Average for Treatments	24	23	23	21	22	26	

No significant difference between treatment averages.

TABLE 17

Mean Number of Leaves per Four Twigs of Hamlins as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	29	23	24	25	22	24	25
April	22	20	20	21	21	22	21
May	21	19	20	19	19	19	20
June	22	23	25	19	19	23	22
July	20	21	21	18	19	24	21
August	16	22	21	17	17	20	19
September	19	22	22	19	18	20	20
October	20	23	21	23	24	23	22
November	21	22	25	20	25	25	23
December	19	22	25	17	25	19	21
January	17	20	22	18	19	22	20
February	17	24	23	18	24	28	22
Average for Treatments	20	22	22	20	21	22	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	2 leaves	3 leaves
Nitrogen Means:	1. 5 leaves	2 leaves

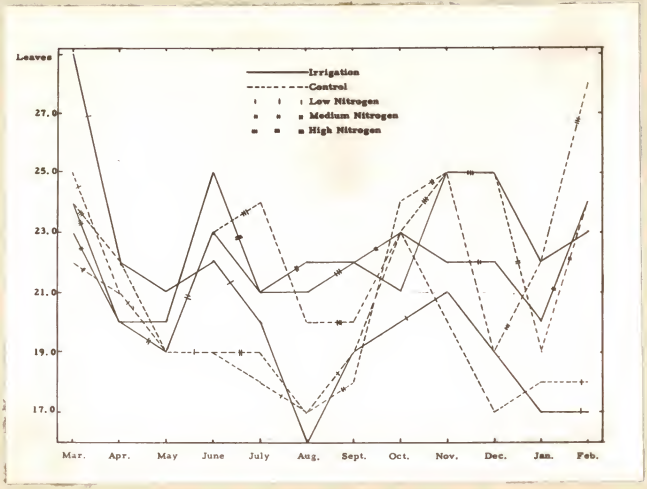


Figure 10. Mean number of leaves per four twigs of Hamlins, 1953-1954 season.

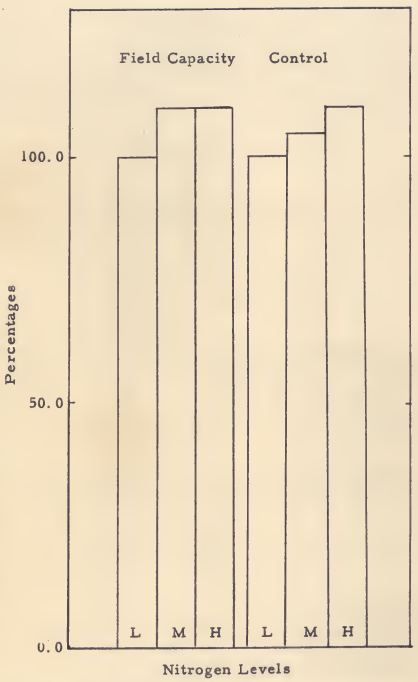


Figure 11. The relationship between nitrogen levels and the seasonal averages for number of leaves per sample of Hamlins, 1953-1954 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen

presented in graphic form in Figure 11, denotes that there is a curvilinear regression correlation coefficient significant at the 1 per cent level.

5. Fresh weight of 30 disks: Tables 18, 19, 20, and 21 summarize the results of determination of the fresh weight of 30 leaf disks of both varieties in the two seasons. A combined table of the analysis of variance for these data is given in Table 7a of the Appendix.

No significant response to the differential treatments has been noticed for the data of the first season. However, the mean fresh weight of 30 disks of satsuma leaves was consistently larger than that of 30 disks of Hamlin leaves.

During the second season, satsumas under high nitrogen treatments showed significantly larger response than those under either low or medium nitrogen treatments. Furthermore, irrigation showed a positive response in the high nitrogen plots, significantly larger than that of the control. Differences in results for the low and medium nitrogen treatments were not significant, either with or without irrigation. The mean fresh weight of 30 disks of satsuma leaves under various treatments throughout the season, presented graphically in Figure 12, shows a definite trend with a minimum average in March and a maximum average in November. Second year data for Hamlins show neither a significant response to the differential treatments nor a similar pattern of seasonal fluctuations.

TABLE 18

Mean Fresh Weight in Grams of Thirty Leaf Disks of Satsumas as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
July	2.07	1.99	2.00	1.94	1.89	2.34	2.04
August	2.13	2.08	2.01	2.04	2.00	1.99	2.04
September	1.97	1.94	1.96	1.89	1.85	1.89	1.92
October	2.00	1.98	1.90	1.74	1.82	1.90	1.89
November	1.99	1.84	1.82	1.83	1.65	1.85	1.83
December	1.95	1.95	1.97	2.00	1.87	1.54	1.88
January	1.89	1.90	2.02	1.84	1.86	1.89	1.90
February	1.98	1.98	2.02	2.00	1.89	2.09	1.99
Average for Treatments	2.00	1.96	1.96	1.91	1.85	1.94	

No significant difference between treatment averages.

TABLE 19

Mean Fresh Weight in Grams of Thirty Leaf Disks of Hamlins as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
July	1.52	1.47	1.52	1.52	1.49	1.52	1.51
August	1.67	1.65	1.66	1.58	1.50	1.61	1.61
September	1.65	1.64	1.60	1.61	1.55	1.70	1.63
October	1.62	1.51	1.59	1.58	1.46	1.52	1.55
November	1.44	1.58	1.51	1.44	1.43	1.46	1.48
December	1.39	1.29	1.36	1.40	1.24	1.38	1.34
January	1.49	1.54	1.55	1.58	1.51	1.47	1.52
February	1.46	1.51	1.50	1.46	1.50	1.45	1.48
Average for Treatments	1.53	1.52	1.54	1.52	1.46	1.51	

No significant difference between treatment averages.

TABLE 20

Mean Fresh Weight in Grams of Thirty Leaf Disks of Satsumas as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	1.75	1.66	1.70	1.70	1.77	1.76	1.72
April	1.93	1.87	1.86	1.88	1.80	1.96	1.88
May	1.85	1.83	1.77	1.83	1.69	1.86	1.81
June	1.86	1.86	1.91	1.83	1.88	1.92	1.88
July	1.88	1.94	1.96	1.91	1.97	1.98	1.94
August	2.05	2.02	2.07	1.98	1.96	2.01	2.02
September	1.93	1.96	1.97	1.87	1.89	1.93	1.93
October	2.00	1.90	2.17	1.94	1.89	2.01	1.99
November	2.05	2.11	2.07	1.93	2.07	1.98	2.04
December	1.87	1.88	1.86	1.84	1.84	1.83	1.85
January	1.80	1.88	1.82	1.88	1.84	1.85	1.85
February	1.84	1.85	1.84	1.81	1.84	1.88	1.84
Average for Treatments	1.90	1.90	1.92	1.87	1.87	1.91	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.04 gm.	0.05 gm.
Nitrogen Means:	0.03 gm.	0.03 gm.
Irrigation Means:	0.02 gm.	0.03 gm.

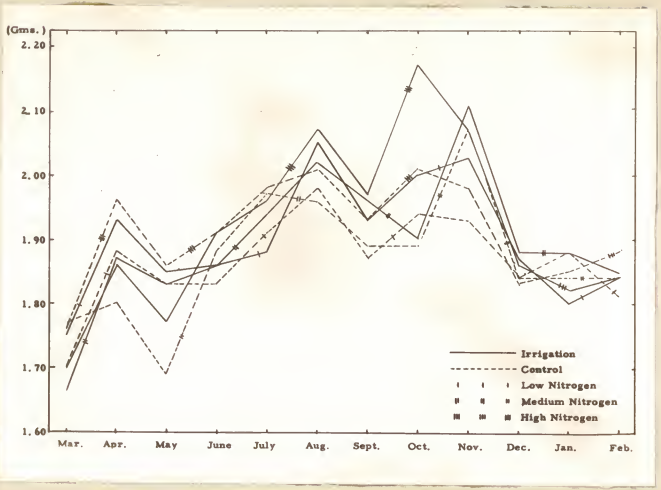


Figure 12. Mean fresh weight in grams of thirty disks of satsuma leaves, 1953-1954 season.

TABLE 21

Mean Fresh Weight in Grams of Thirty Leaf Disks of Hamlins as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	1.41	1.37	1.42	1.47	1.43	1.35	1.41
April	1.36	1.34	1.32	1.34	1.26	1.34	1.33
May	1.34	1.35	1.37	1.37	1.34	1.30	1.36
June	1.33	1.37	1.33	1.37	1.39	1.32	1.35
July	1.37	1.34	1.33	1.37	1.24	1.30	1.33
August	1.34	1.41	1.40	1.33	1.31	1.38	1.36
September	1.55	1.52	1.53	1.51	1.53	1.50	1.52
October	1.44	1.42	1.40	1.39	1.42	1.45	1.42
November	1.41	1.39	1.36	1.42	1.42	1.44	1.41
December	1.43	1.44	1.41	1.41	1.39	1.44	1.42
January	1.49	1.49	1.49	1.51	1.52	1.51	1.50
February	1.50	1.43	1.46	1.46	1.48	1.41	1.46
Average for Treatments	1.41	1.41	1.40	1.41	1.39	1.40	

No significant difference between treatment averages.

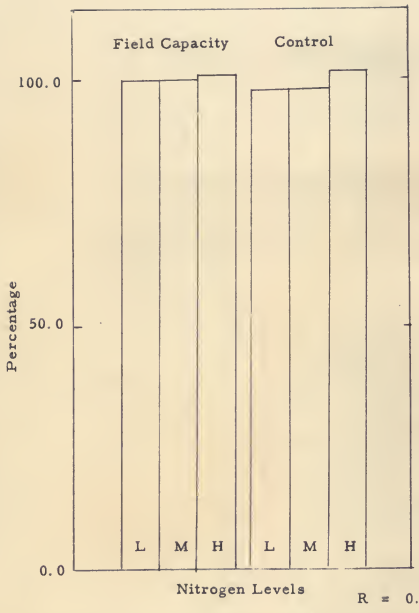


Figure 13. The relationship between nitrogen levels and the seasonal average for the fresh weight of thirty disks of satsuma leaves, 1953-1954 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen

A relationship between the differential nitrogen levels and the relative mean fresh weight of 30 disks of satsuma leaves is demonstrated graphically in Figure 13. It has a curvilinear correlation coefficient significant at the 1% level.

6. Dry weight per leaf: Results of determinations of the average dry weight of one leaf of Hamlin and satsuma are presented in Tables 22, 23, 24, and 25. A combined analysis of variance for these tables is given in Table 8a of the Appendix.

Neither the Hamlins nor the satsumas showed any correlation of average leaf weight with the treatments during the first season. However, the maximum averages for both varieties were attained in November, and the mean dry weight of a leaf was consistently greater for satsumas than for Hamlins.

During the second season, the Hamlins did not respond to the treatments, but the satsumas gave a significant response to the differential nitrogen applications. Trees in the low nitrogen plots had average leaf weights significantly lower than those in the medium or high nitrogen plots, the differences being significant at the 1% level in the plots maintained at field capacity, and at the 5% level for the plots without moisture control. In both sets of plots the differences between medium and high nitrogen treatments were not significant.

Fluctuations in average dry weight per leaf for satsumas during the 1953-1954 season are shown graphically in Figure 14. For all

TABLE 22

Mean Dry Weight in Milligrams per Leaf of Satsumas as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	254	283	270	259	287	263	269
July	207	264	259	254	256	270	252
August	262	323	296	286	264	310	290
September	258	316	281	281	298	284	286
October	309	281	295	375	320	351	322
November	279	334	306	351	393	347	335
December	277	304	309	362	248	330	305
January	221	308	283	353	281	311	293
February	202	326	296	288	314	327	292
Average for Treatments	252	304	288	312	296	310	

No significant difference between treatment averages.

TABLE 23

Mean Dry Weight in Milligrams per Leaf of Hamlins as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
July	234	199	197	195	229	244	216
August	184	263	210	238	212	245	225
September	197	257	202	207	241	229	222
October	223	231	227	236	233	297	241
November	227	250	253	290	268	239	255
December	237	239	217	264	286	252	249
January	226	225	205	264	260	234	236
February	137	123	111	125	111	117	121
Average for Treatments	208	223	203	227	230	232	

No significant difference between treatment averages.

TABLE 24

Mean Dry Weight in Milligrams per Leaf of Satsumas as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	94	92	114	109	157	157	121
April	181	248	305	233	299	330	266
May	194	394	323	313	314	293	305
June	186	305	308	233	320	284	273
July	186	307	321	238	328	277	276
August	209	273	249	229	287	255	250
September	181	280	324	231	280	235	255
October	199	298	314	255	335	241	274
November	224	340	322	247	306	262	284
December	162	331	341	226	287	278	271
January	177	313	357	327	326	360	310
February	297	405	438	324	370	340	362
Average for Treatments	191	299	310	247	301	276	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	63 mg.	87 mg.
Nitrogen Means:	44 mg.	62 mg.

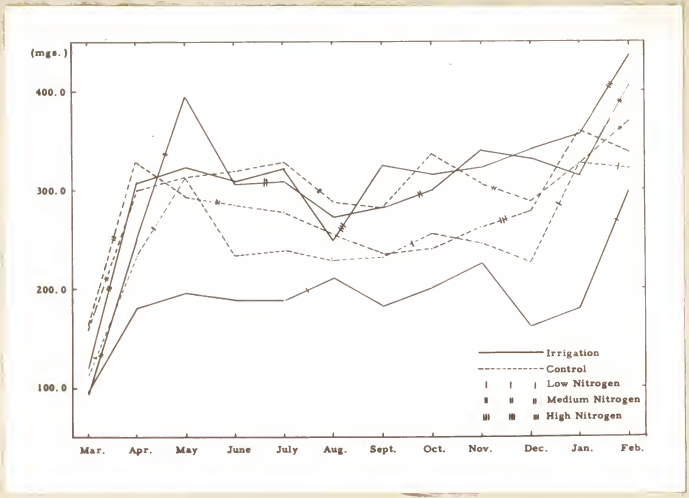


Figure 14. Mean dry weight in milligrams per leaf of satsumas as affected by varying soil moisture and nitrogen application levels, 1953-1954 season.

TABLE 25

Mean Dry Weight in Milligrams per Leaf of Hamlins as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	123	128	132	119	129	115	124
April	132	144	153	146	155	136	144
May	157	161	158	176	166	150	161
June	163	142	173	128	166	141	152
July	123	178	182	146	193	148	162
August	134	157	174	137	180	154	156
September	125	155	178	163	154	152	155
October	148	158	174	159	168	172	163
November	164	160	176	169	192	156	170
December	176	152	182	145	140	171	161
January	136	146	167	183	143	162	156
February	165	195	175	173	198	177	181
Average for Treatments	146	156	169	154	165	153	

No significant difference between treatment averages.

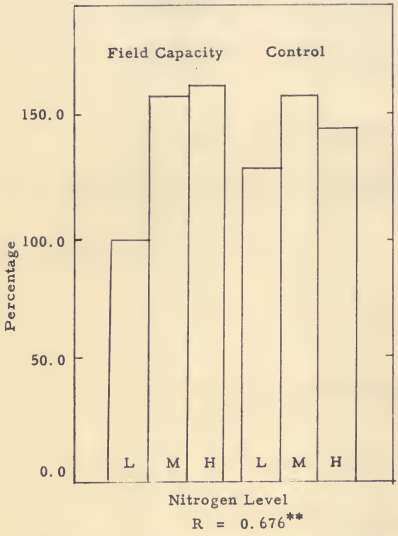


Figure 15. The relationship between nitrogen levels and the seasonal averages for dry weight per leaf of satsumas, 1953-1954 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen

treatments, the average leaf weight is minimum in March when the leaves are just starting the season, and reaches a maximum the following February. The values of leaf dry weight for each treatment maintained the same relative positions throughout the season. The average leaf weight for Hamlins shows a very similar seasonal pattern. The mean dry weight per leaf was consistently greater for satsumas than for Hamlins throughout the second season also.

The histogram of Figure 15 shows the relationship of the relative values of average dry weight per leaf for satsumas to the different treatments employed. The correlation coefficient of its curvilinear regression was found to be significant at the 1 per cent level.

7. Chlorophyll content of 30 disks: Data for chlorophyll content of 30 disks of leaves of Hamlin oranges and satsumas are presented in Tables 26, 27, 28, and 29. A combined table of the analysis of variance for these results is given in Tables 9a and 9b of the Appendix.

During the first season, both Hamlins and satsumas showed significant response to the differential nitrogen applications, at the 1 and 5 per cent levels respectively, while irrigation induced no particular response. The chlorophyll content of leaves from satsuma trees in the low and medium nitrogen plots, with and without irrigation, was significantly lower than that for the high nitrogen levels. The medium nitrogen plots, however, did not give values differing significantly

TABLE 26

Seasonal Changes in Total Chlorophyll Content in Milligrams per 130 cm.^{2} of Satsuma Leaves as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	8.3	8.2	9.0	8.9	8.4	9.4	8.7
July	11.1	10.4	11.9	10.0	10.5	11.3	10.9
August	11.6	10.9	12.4	11.9	10.6	11.9	11.6
September	12.4	12.1	12.5	12.8	12.1	12.4	12.4
October	12.1	12.4	12.7	12.3	12.4	12.4	12.4
November	12.5	12.3	12.4	13.1	12.5	12.9	12.6
December	10.2	12.0	12.1	11.2	12.5	12.3	11.7
January	9.9	10.9	12.5	11.8	12.9	12.1	11.7
February	8.1	9.6	10.3	9.0	11.4	11.5	10.0
Average for Treatments	10.7	11.0	11.8	11.2	11.5	11.8	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.9 mg.	1.2 mg.
Nitrogen Means:	0.6 mg.	0.9 mg.
Time Means:	0.6 mg.	0.8 mg.

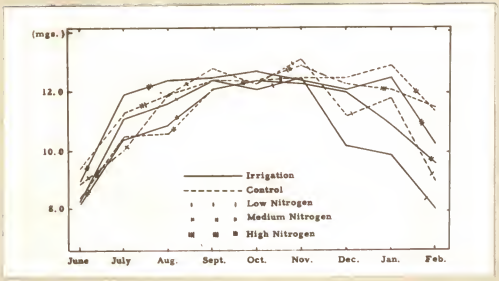


Figure 16. Seasonal changes in chlorophyll content in milligrams per 130 $cm.^2$ of satsuma leaves during the 1952-1953 season.

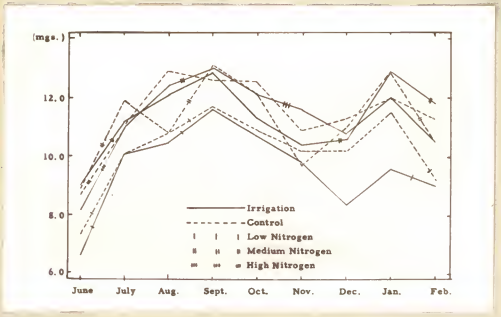


Figure 17. Seasonal changes in chlorophyll content in milligrams per 130 $cm.^2$ of Hamlin leaves during the 1952-1953 season.

TABLE 27

Seasonal Changes in Total Chlorophyll Content in Milligrams per 130 cm.^{2} of Hamlin Leaves as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	6.6	9.0	8.2	7.3	8.9	8.7	8.1
July	10.1	11.2	11.0	10.1	11.9	11.0	10.8
August	10.5	12.1	12.4	10.8	10.8	12.9	11.6
September	11.6	12.8	13.0	11.7	13.1	12.6	12.5
October	10.7	11.3	12.1	10.9	12.1	12.5	11.6
November	9.8	10.4	11.6	10.2	9.7	10.9	10.4
December	8.4	10.5	10.8	10.2	11.0	11.3	10.4
January	9.6	12.9	12.0	11.5	12.8	12.0	11.8
February	9.0	11.8	10.5	9.2	10.5	11.3	10.4
Average for Treatments	9.6	11.3	11.3	10.2	11.2	11.5	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	1.2 mg.	1.8 mg.
Nitrogen Means:	0.9 mg.	1.2 mg.
Time Means:	0.5 mg.	0.7 mg.

TABLE 28

Seasonal Changes in Total Chlorophyll Content in Milligrams per 130 cm.^{2} of Satsuma Leaves as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	4.4	4.5	4.8	4.4	4.7	5.0	4.6
April	5.5	6.1	6.9	7.1	7.5	8.4	6.9
May	9.1	8.8	9.7	10.2	10.8	10.5	9.9
June	9.3	10.0	11.4	10.2	11.6	11.3	10.6
July	11.2	12.6	12.8	10.9	13.8	13.3	12.4
August	12.3	13.5	13.9	12.8	13.7	13.7	13.3
September	12.2	13.8	13.3	12.8	13.6	13.3	13.2
October	13.4	14.6	15.6	13.7	15.8	15.4	14.8
November	12.6	14.0	14.5	12.7	15.0	14.7	13.9
December	11.8	13.9	14.4	13.3	13.7	14.2	13.6
January	12.3	14.6	15.8	13.0	14.8	14.3	14.1
February	9.2	13.7	13.3	10.1	13.6	13.4	12.2
Average for Treatments	10.3	11.7	12.2	10.9	12.4	12.3	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.5 mg.	0.7 mg.
Nitrogen Means:	0.4 mg.	0.5 mg.
Irrigation Means:	0.3 mg.	0.4 mg.
Time Means:	0.5 mg.	0.7 mg.

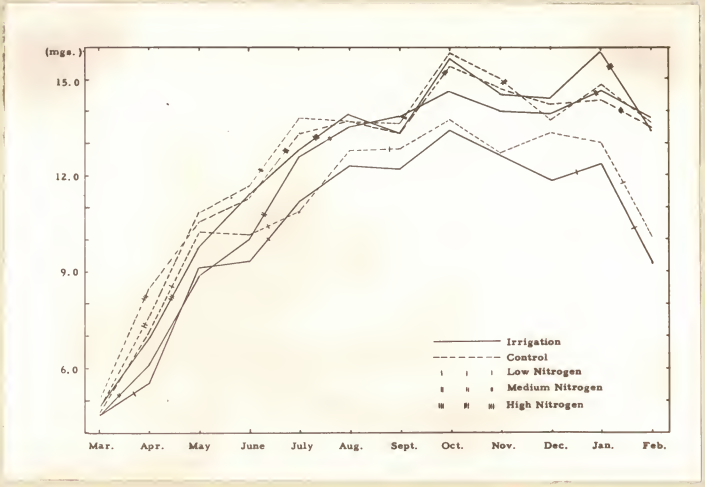


Figure 18. Seasonal changes in chlorophyll content in milligrams per 130 cm.^{2} of satsuma leaves during the 1953-1954 season.

TABLE 29

Seasonal Changes in Total Chlorophyll Content in Milligrams per 130 cm.^{2} of Hamlin Leaves as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	4.9	5.1	5.7	5.0	5.3	5.8	5.3
April	6.0	7.8	7.8	6.5	8.0	7.6	7.3
May	7.7	8.4	9.1	8.7	9.6	9.1	8.8
June	7.2	9.2	10.0	7.8	9.0	9.5	8.8
July	10.4	12.0	11.8	10.7	11.8	12.5	11.5
August	10.9	13.5	13.2	10.5	12.4	13.8	12.4
September	10.7	12.4	12.6	11.0	12.9	12.8	12.1
October	10.6	12.5	12.9	10.8	12.1	12.6	11.9
November	10.9	11.9	12.2	9.6	11.8	12.7	11.5
December	11.5	13.0	12.7	10.8	12.8	12.9	12.3
January	10.9	12.4	12.6	11.0	12.7	13.2	12.1
February	11.5	13.2	13.2	11.6	13.3	13.0	12.6
Average for Treatments	9.4	10.6	11.2	9.5	11.0	11.3	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.8 mg.	1.1 mg.
Nitrogen Means:	0.5 mg.	0.8 mg.
Time Means:	0.4 mg.	0.5 mg.

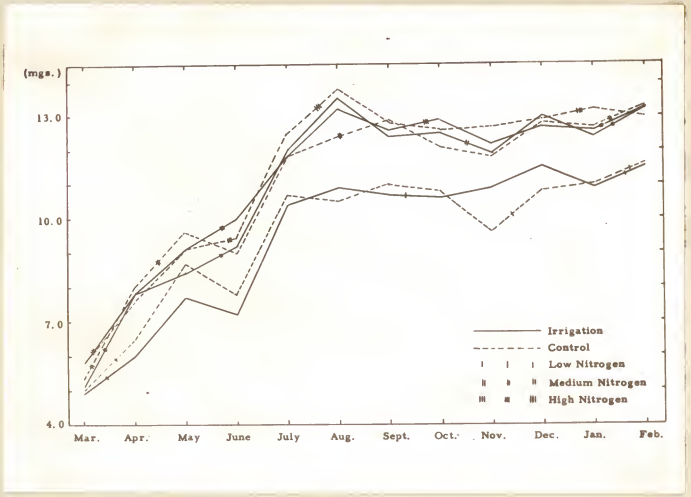


Figure 19. Seasonal changes in chlorophyll content in milligrams per 130 cm.^{2} of Hamlin leaves during the 1953-1954 season.

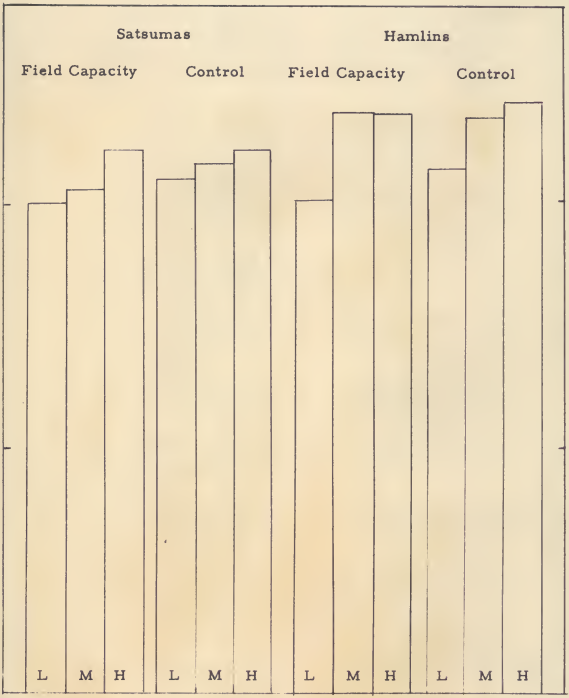
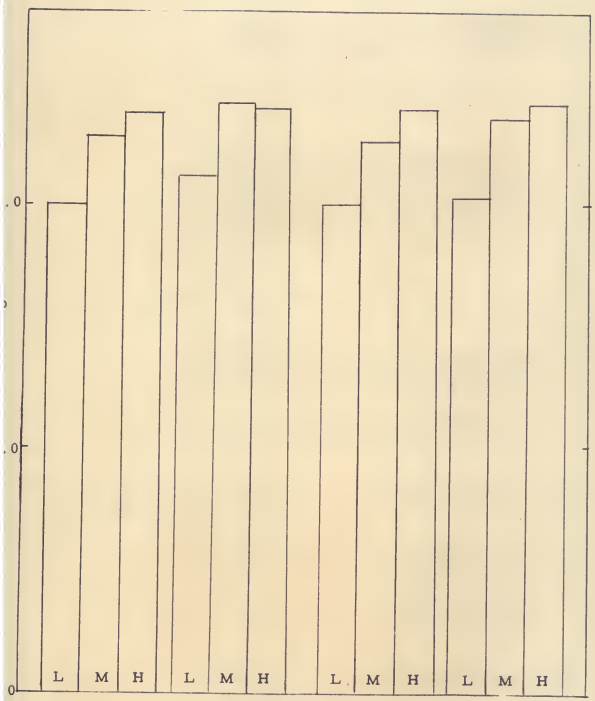


Figure 20. The relationship between nitrogen levels and the seasonal averages for chlorophyll content per thirty disks of leaves, 1952-1953 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen.



$R = 0.913^{**}$, $r = 0.845^{*}$ $R = 0.923^{**}$, $r = 0.800^{**}$

Figure 21. The relationship between nitrogen levels and the seasonal averages for chlorophyll content per thirty disks of leaves, 1953-1954 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen

from those of low nitrogen plots. In the Hamlins, also, both of the low nitrogen treatments showed responses significantly lower, at 1 per cent, than those of medium and high nitrogen levels; and differences in chlorophyll content between the medium and the high levels of nitrogen were not significant, nor were differences due to irrigation. A pooled analysis of variance of data for both varieties during both seasons is presented in Table 10a of the Appendix. This analysis confirms the finding that the two varieties were different in their responses to the differential nitrogen levels, so far as chlorophyll content of the 1952-1953 season is concerned.

During the second season, in both Hamlins and satsumas, the differences between low and medium, and between medium and high nitrogen treatments were highly significant in the irrigated plots; but in the non-irrigated plots only the differences between low nitrogen and medium or high nitrogen were significant, the latter two treatments not differing significantly. In comparing irrigation treatments, it is seen that for satsumas the low and medium nitrogen plots had significantly lower chlorophyll values with irrigation than without it; but the high nitrogen treatments on satsumas showed no differences due to irrigation, nor did any of the Hamlin plots.

When these data are plotted in graphic form, further differences in the response of the two varieties to treatments are obvious. Figures 16, 17, 18, and 19 contain these graphs. In both seasons the chlorophyll

content of satsuma leaves (Figures 16 and 18) increases to a maximum in October or November from the initial low value at the beginning of the season, and then falls off to a second minimum in February at the end of the season. In the case of Hamlin leaves (Figures 17 and 19) the maximum values are attained in August or September, with a small decrease for about two months and then little change throughout the rest of the season. It is interesting to note that for both varieties the maximum chlorophyll value was reached one month earlier in 1953-1954 than in 1952-1953. With some fluctuations, more striking in the satsumas than in the Hamlins, the chlorophyll values for the various treatments maintained their relative positions fairly well throughout both seasons.

During the first season, the average chlorophyll content was almost the same for Hamlin and satsuma leaves from June to September, but for the remainder of the season the satsumas had slightly higher values. In the second season, Hamlin leaves exceeded satsuma leaves in average chlorophyll content during February and March, but for the remaining ten months of the season, the satsuma leaves had higher values.

From the histograms of the relationship between nitrogen levels and the relative chlorophyll contents of leaves of both varieties, shown in Figures 20 and 21, it is determined that the correlation coefficients of their curvilinear regression are significant at the 5% level in 1952-1953 and at the 1% level in 1953-1954.

8. Nitrogen percentage of leaves on dry weight basis: Data on nitrogen percentage of leaves of Hamlin oranges and satsumas are presented in Tables 30, 31, 32, and 33. A combined analysis of variance for these tables is given in Tables 11a and 11b of the Appendix.

During the 1952-1953 season, differences in nitrogen percentage of leaves were not significant between irrigated and control plots. For satsumas, the high nitrogen plots gave percentages of leaf nitrogen which were significantly (1% level) larger than those from the low nitrogen plots in both cases, and in the control series the differences were significant at the 5% level between low and medium, and between medium and high nitrogen plots. In the irrigated series the medium nitrogen plot did not give values differing significantly from either low or high nitrogen. For the Hamlin orange leaves, the only significant differences in nitrogen content were those between the low and either medium or high nitrogen plots of the irrigated series. Satsuma leaves from high nitrogen plots averaged higher in nitrogen than Hamlin leaves from the same plots, but there were no consistent differences between these varieties under the other levels of soil nitrogen.

Graphic presentation of these data in Figures 22 and 23 brings out the fact that the percentage nitrogen content of satsuma leaves was correlated throughout the season with the nitrogen level of the soil in which the trees grew, whereas the Hamlin leaves do not show such seasonal correlation consistently except for the low nitrogen plot of the

TABLE 30

Seasonal Fluctuations in Mean Nitrogen Percentages of Satsuma Leaves as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	2.81	2.74	3.19	2.52	2.94	3.23	2.91
July	2.53	2.66	3.02	2.52	2.90	3.17	2.80
August	2.47	2.62	2.86	2.53	2.66	3.00	2.69
September	2.48	2.59	2.76	2.46	2.58	2.77	2.61
October	2.80	2.73	2.90	2.71	2.83	2.97	2.82
November	2.65	2.72	2.94	2.62	2.64	2.89	2.74
December	2.51	2.78	3.02	2.50	2.79	3.12	2.79
January	2.41	2.59	2.61	2.57	2.84	2.81	2.64
February	2.37	2.55	2.57	2.42	2.79	2.98	2.61
Average for Treatments	2.56	2.66	2.87	2.54	2.77	2.99	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.20%	0.28%
Nitrogen Means:	0.14%	0.19%
Time Means:	0.11%	0.14%

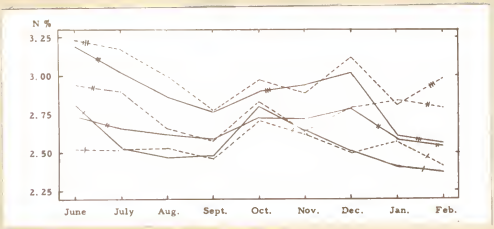


Figure 22. Seasonal flucutuations in mean nitrogen percentages of satsuma leaves during the 1952-1953 season.

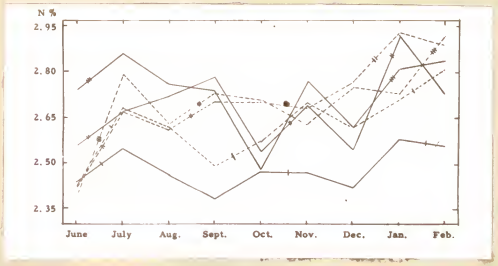


Figure 23. Seasonal fluctuations in mean nitrogen percentages of Hamlin leaves during the 1952-1953 season.

TABLE 31

Seasonal Flucutuations in Mean Nitrogen Percentages of Hamlin Leaves as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	2.44	2.56	2.74	2.43	2.42	2.39	2.50
July	2.55	2.67	2.86	2.68	2.67	2.79	2.70
August	2.46	2.72	2.76	2.62	2.61	2.63	2.63
September	2.37	2.78	2.74	2.49	2.70	2.73	2.64
October	2.47	2.54	2.48	2.57	2.70	2.71	2.58
November	2.47	2.69	2.77	2.70	2.68	2.63	2.66
December	2.42	2.55	2.62	2.62	2.77	2.75	2.62
January	2.58	2.92	2.81	2.71	2.93	2.73	2.78
February	2.56	2.73	2.84	2.81	2.89	2.92	2.79
Average for Treatments	2.48	2.68	2.74	2.63	2.71	2.70	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.16%	0.22%
Nitrogen Means:	0.11%	0.16%
Time Means	0.12%	0.16%

TABLE 32

Seasonal Fluctuations in Mean Nitrogen Percentages of Satsuma Leaves as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	3.84	4.24	4.32	3.94	4.16	4.38	4.15
April	2.34	2.68	2.93	2.68	3.08	3.24	2.83
May	2.51	3.01	3.08	2.83	3.20	3.26	2.98
June	2.56	3.01	3.18	2.92	3.26	3.32	3.04
July	2.65	3.02	3.23	2.81	3.34	3.37	3.07
August	2.71	2.95	3.25	2.65	3.29	3.31	3.03
September	2.80	2.94	3.00	3.02	2.99	3.27	3.00
October	2.85	3.11	3.19	3.08	3.28	3.38	3.15
November	2.72	2.88	3.06	2.77	3.09	3.06	2.93
December	2.77	3.08	3.24	2.86	3.24	3.24	3.07
January	2.61	2.85	2.79	2.65	3.05	3.24	2.87
February	2.56	2.81	2.90	2.55	2.93	2.94	2.78
Average for Treatments	2.74	3.05	3.18	2.90	3.24	3.33	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.19%	0.26%
Nitrogen Means:	0.13%	0.18%
Irrigation Means:	0.11%	0.15%
Time Means:	0.11%	0.14%

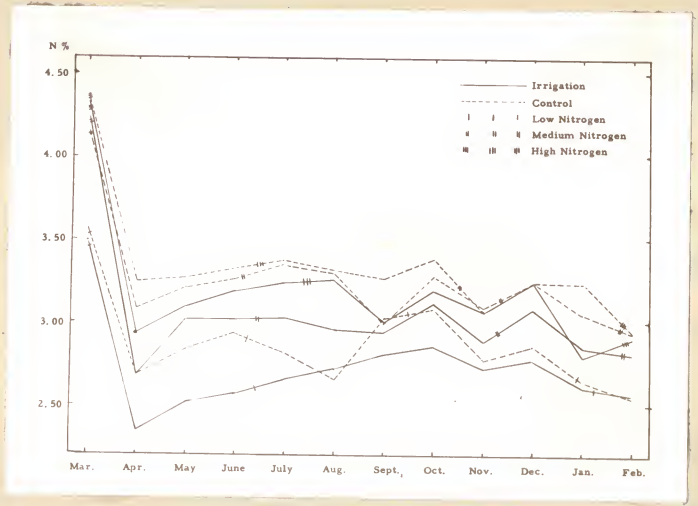


Figure 24. Seasonal fluctuations in mean nitrogen percentages of satsuma leaves during the 1953-1954 season.

TABLE 33

Seasonal Fluctuations in Mean Nitrogen Percentages of Hamlin Leaves as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	2.61	2.94	2.95	2.65	3.11	2.73	2.82
April	2.61	2.95	2.82	2.48	2.99	2.91	2.79
May	2.59	2.87	2.91	2.79	3.08	3.12	2.89
June	2.44	2.89	2.96	2.68	2.93	3.09	2.83
July	2.61	2.96	3.08	2.88	3.15	3.22	2.98
August	2.22	2.87	2.98	2.58	3.10	3.03	2.80
September	2.44	2.78	2.91	2.65	2.96	2.76	2.75
October	2.71	2.80	3.03	2.78	2.90	3.08	2.88
November	2.47	2.82	2.89	2.75	3.07	3.06	2.84
December	2.44	2.97	2.97	2.74	3.00	3.03	2.86
January	2.61	3.08	3.13	2.88	3.23	3.33	3.04
February	2.29	2.86	2.94	2.55	2.81	2.78	2.71
Average for Treatments	2.50	2.90	2.96	2.70	3.03	3.01	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.31%	0.44%
Nitrogen Means:	0.22%**	0.31%
Time Means:	0.11%	0.14%

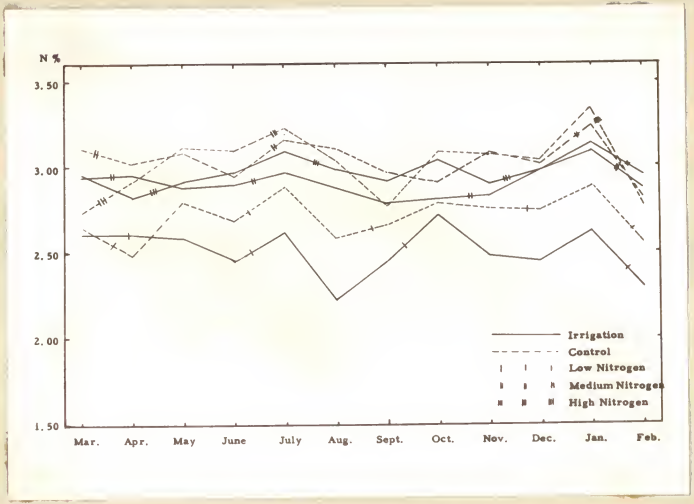


Figure 25. Seasonal fluctuations in mean nitrogen percentages of Hamlin leaves during the 1953-1954 season.

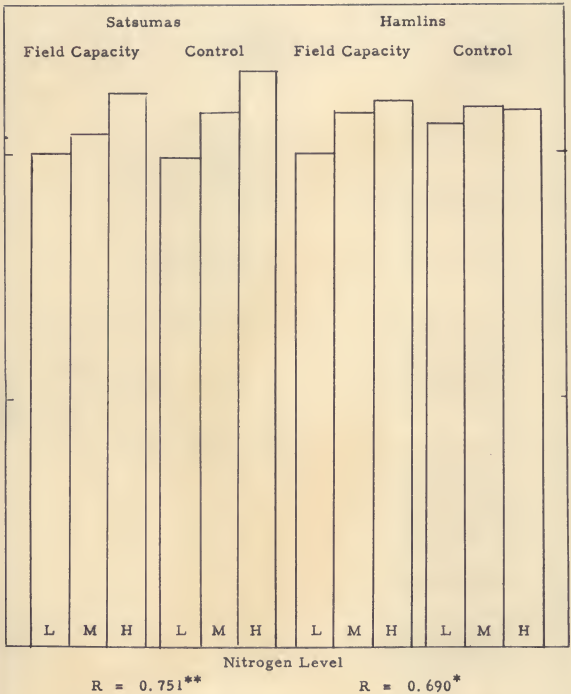
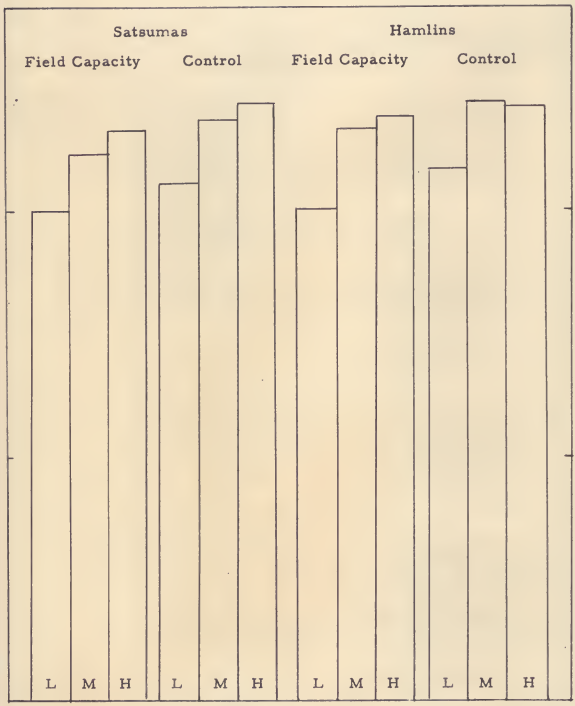


Figure 26. The relationship between nitrogen levels and the seasonal averages for nitrogen percentage of leaves, 1952-1953 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen



$R = 0.885^{**}$, $r = 0.853^{**}$ $R = 0.769^{**}$, $r = 0.686^{**}$

Figure 27. The relationship between nitrogen levels and the seasonal averages for nitrogen percentage of leaves, 1953-1954 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen

irrigated series being always lowest in leaf nitrogen. It is seen, also, that whereas satsuma leaves had their highest values in June and were lowest at the end of the season in February, the Hamlin leaves were highest in leaf nitrogen in February, and rose from a low June value, although in some plots there was a still lower point reached in September or October.

The relationship between the differential nitrogen levels and the relative nitrogen percentage is presented in a graphic form for both varieties in Figure 26. Evaluation of their curvilinear regression correlation indicates the existence of significant correlation at the 1 per cent level in satsuma and at the 5 per cent level in Hamlins.

During the 1953-1954 season, irrigation induced a highly significant response, lower than that of the control, only for satsumas. Furthermore, differential nitrogen levels induced highly significant responses in both varieties. Low nitrogen plots, in both varieties, showed significantly lower values of leaf nitrogen, at the 1 per cent level, than those of either the medium or the high nitrogen plots; but there was no significant difference between the responses of medium and high nitrogen plots for either variety, with the exception of the irrigated satsuma plots. Mean nitrogen percentage of satsuma leaves was consistently greater than that of the Hamlin leaves for all plots. A pooled analysis of data for both varieties disclosed that the two varieties were not different in the trends of their responses to the differential nitrogen

levels, so far as nitrogen percentage was concerned.

Both varieties showed highly significant seasonal changes in nitrogen percentages. These cases are presented in graphic form in Figures 24 and 25. In the satsumas, there is a notable maximum of leaf nitrogen (as per cent of dry weight) in the new flush in March, falling quickly to a fairly constant value which diminishes slowly to a minimum at the end of the season in February. The Hamlin leaves are strikingly different. The percentage of leaf nitrogen shows no consistent change during the early part of the season, although there is a tendency to a low in early fall. In January there is a maximum value for most plots, which drops quickly to a low in February. Furthermore, the values for nitrogen percentage under various treatments, in both varieties, maintained the same relative positions throughout the season.

The relationship between the differential nitrogen levels and the relative nitrogen percentage is demonstrated graphically for both varieties in Figure 27. Evaluation of their curvilinear regression correlation indicated the existence of a highly significant correlation in both cases.

9. Total nitrogen content per sample: Data on total nitrogen content of samples of Hamlin and satsuma leaves are presented in Tables 34, 35, 36, and 37. A summary of the analysis of variance for these data is given in Table 13a of the Appendix.

During the first season, neither variety showed significant

TABLE 34

Mean Total Nitrogen Content in Milligrams of the Satsuma Leaves on Three Twigs, as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	254	297	274	294	290	296	284
July	285	232	321	301	280	321	290
August	242	292	281	280	265	329	282
September	249	312	308	321	227	365	297
October	361	341	277	355	350	372	343
November	324	374	313	371	362	329	346
December	331	319	396	336	329	430	357
January	209	291	254	311	299	327	282
February	215	292	339	288	379	419	322
Average for Treatments	274	306	307	317	309	354	

No significant difference between treatment averages.

TABLE 35

Mean Total Nitrogen Content in Milligrams of the Hamlin Leaves on Four Twigs, as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
July	159	164	175	164	177	241	180
August	138	198	200	187	165	210	183
September	174	178	188	198	171	183	182
October	147	158	208	162	182	223	180
November	122	164	201	208	177	154	171
December	179	194	173	188	176	238	191
January	175	211	204	223	214	164	199
February	129	116	113	136	142	130	128
Average for Treatments	153	173	183	183	176	193	

No significant difference between treatment averages.

TABLE 36

Mean Total Nitrogen Content in Milligrams of the Satsuma Leaves on Three Twigs, as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	88	84	117	116	124	155	114
April	96	123	173	136	189	234	159
May	164	256	218	181	219	262	217
June	114	195	225	107	215	198	176
July	87	216	232	125	242	283	198
August	170	181	217	143	251	226	198
September	117	214	278	161	257	247	212
October	136	216	203	157	185	199	183
November	140	194	220	154	195	237	190
December	109	234	219	114	192	224	182
January	110	252	211	132	179	256	190
February	168	300	247	169	252	276	235
Average for Treatments	125	205	213	141	208	233	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	34 mg.	48 mg.
Nitrogen Means:	24 mg.	34 mg.

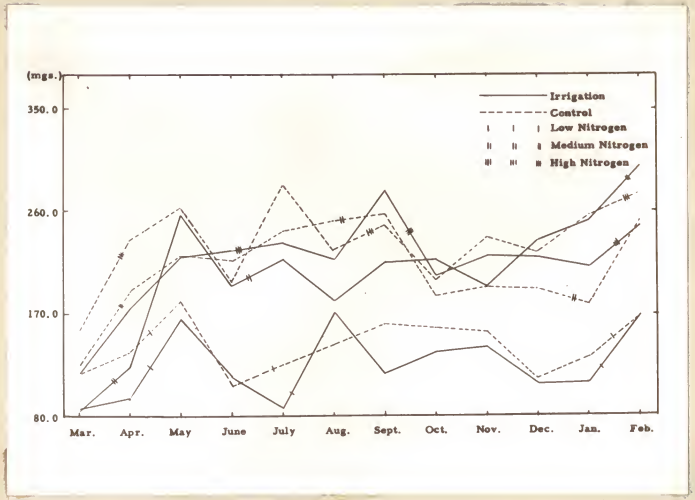


Figure 28. Seasonal trends in mean total nitrogen content in milligrams of the satsuma leaves per sample of three twigs during the 1953-1954 season.

TABLE 37

Mean Total Nitrogen Content in Milligrams of the Hamlin Leaves on Four Twigs, as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	94	85	93	78	88	77	86
April	77	85	84	75	97	86	84
May	82	91	90	90	97	88	90
June	87	93	127	65	91	97	93
July	63	112	119	75	116	112	100
August	48	98	105	60	93	91	83
September	59	95	111	84	80	83	85
October	81	99	112	101	115	121	105
November	86	102	123	95	149	119	112
December	80	102	134	69	105	100	98
January	61	90	113	97	89	116	94
February	64	132	117	81	132	138	111
Average for Treatments	74	99	111	81	104	102	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	14 mg.	19 mg.
Nitrogen Means:	10 mg.	14 mg.

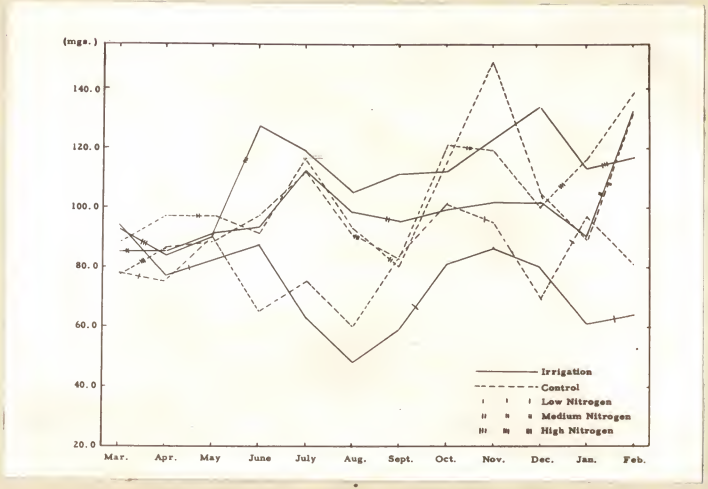


Figure 29. Seasonal trends in mean total nitrogen content in milligrams of the Hamlin leaves per sample of four twigs during the 1953-1954 season.

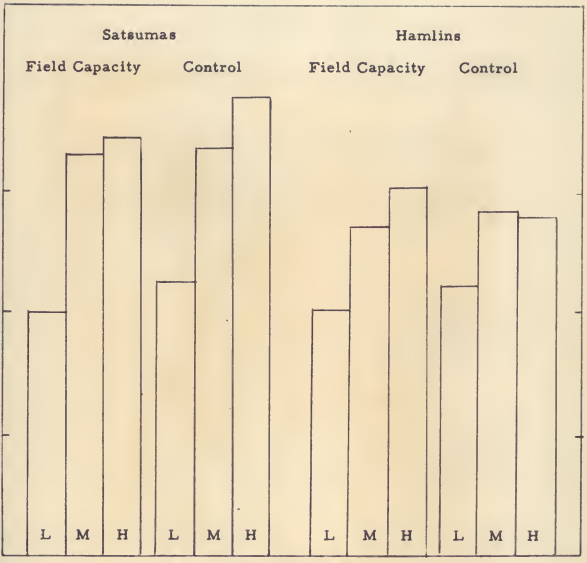


Figure 30. The relationship between nitrogen levels and the seasonal averages for total nitrogen of leaves per sample, 1953-1954 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen

response to treatments, although the mean total nitrogen content of the sample of satsuma leaves was consistently greater than that of the sample of Hamlin leaves.

Data for the second season did not show any significant response to irrigation. However, differential nitrogen levels induced highly significant responses in both varieties. Low nitrogen treatments, in both cases, gave values of total nitrogen significantly lower, at the 1 per cent level, than did either the medium or the high nitrogen treatments. The medium nitrogen plots, however, did not give values differing significantly from high nitrogen. Again, the mean total nitrogen content of satsuma leaves was consistently greater than that of the Hamlin leaves. A pooled analysis of variance of data for both varieties, given in Table 14a of the Appendix, revealed that the varieties were significantly different in their responses to the differential nitrogen levels.

A study of the seasonal trends for both varieties, as shown in Figures 28 and 29, indicates that samples of both varieties under all treatments ended the season with higher nitrogen contents than they had in March, except for the irrigated low nitrogen plot of Hamlins. The value in February at the season's end is maximum in all cases for satsumas, and the increase in value from March to May is rapid. This spring rise is not shown by the Hamlins, and while the end-season values in February are high, they are not the maximum values in most

treatments.

Further studies on the relationship between the differential nitrogen levels and the relative total nitrogen content of leaf samples, are presented in Figure 30 for both Hamlins and satsumas. An evaluation of their curvilinear regression correlation indicates the existence of a highly significant correlation in each case.

10. Nitrogen content per leaf: Results of determination of the average nitrogen content of satsuma and Hamlin leaves are presented in Tables 38, 39, 40, and 41. A combined analysis of variance for these tables is given in Table 15a of the Appendix.

During the first season, neither variety showed any significant response to the treatments. However, the mean nitrogen content of a satsuma leaf was consistently greater than that of the leaf of a Hamlin.

Data for the second season did not reveal a significant response to irrigation. However, differential nitrogen levels induced a highly significant response in both varieties. The low nitrogen plots had leaves with average nitrogen content significantly lower, at the 1 per cent level, than those of medium or high nitrogen plots. However, there was no significant difference in response between the medium and the high nitrogen plots. The mean nitrogen content of a leaf was consistently greater for satsumas than for Hamlins. A pooled analysis of variance of data for both varieties, given in Table 16a of the Appendix, revealed that the two varieties acted differently in their responses to the

TABLE 38

Mean Nitrogen Content in Milligrams of an Average Satsuma Leaf as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
June	7.0	7.8	8.7	6.4	8.5	8.4	7.8
July	5.2	6.9	7.8	6.3	7.4	8.4	7.0
August	6.5	8.5	8.6	7.2	7.1	9.4	7.9
September	6.4	8.2	7.7	7.0	7.6	8.0	7.5
October	8.7	7.7	8.6	10.1	9.0	10.5	9.1
November	7.4	9.0	9.1	9.1	10.5	10.0	9.2
December	7.0	8.5	9.4	9.1	7.0	10.3	8.6
January	5.3	7.9	7.4	9.1	8.0	8.8	7.8
February	4.8	8.3	7.4	6.9	8.7	9.7	7.6
Average for Treatments	6.5	8.1	8.3	7.9	8.2	9.3	

No significant difference between treatment averages.

TABLE 39

Mean Nitrogen Content in Milligrams of an Average Hamlin Leaf as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1952-1953 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
July	5.9	5.3	5.7	5.2	6.1	6.9	5.9
August	4.5	7.2	5.8	6.2	5.6	6.4	6.0
September	5.0	7.0	5.5	5.1	6.5	6.2	5.9
October	5.5	5.9	5.7	6.1	6.3	7.9	6.2
November	5.6	6.7	7.0	7.8	7.2	6.3	6.8
December	5.8	6.1	5.7	6.9	7.9	7.0	6.6
January	5.8	6.6	5.8	7.2	7.7	6.4	6.6
February	3.6	3.4	3.1	3.5	3.2	3.7	3.4
Average for Treatments	5.2	6.0	5.5	6.0	6.3	6.4	

No significant difference between treatment averages.

TABLE 40

Mean Nitrogen Content in Milligrams of an Average Satsuma Leaf as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	3.6	3.9	4.9	4.3	6.3	6.7	5.0
April	4.2	6.7	8.9	6.2	9.2	10.7	7.7
May	4.9	11.9	9.9	8.8	10.1	9.5	9.2
June	4.9	9.1	9.8	6.8	10.4	9.4	8.4
July	4.9	9.3	10.4	6.6	11.0	9.3	8.6
August	5.7	8.1	8.1	6.1	9.5	8.4	7.7
September	5.1	8.3	9.7	7.0	8.4	7.8	7.7
October	5.7	9.3	10.0	7.9	10.9	8.1	8.7
November	6.2	9.8	9.9	7.0	9.5	8.1	8.4
December	4.6	10.3	11.0	6.5	9.2	9.1	8.5
January	4.7	8.8	10.0	8.7	9.9	11.7	9.0
February	7.6	11.5	12.7	8.3	10.8	9.9	10.1
Average for Treatments	5.2	8.9	9.6	7.0	9.6	9.1	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	1.9 mg.	2.6 mg.
Nitrogen Means:	1.3 mg.	1.8 mg.

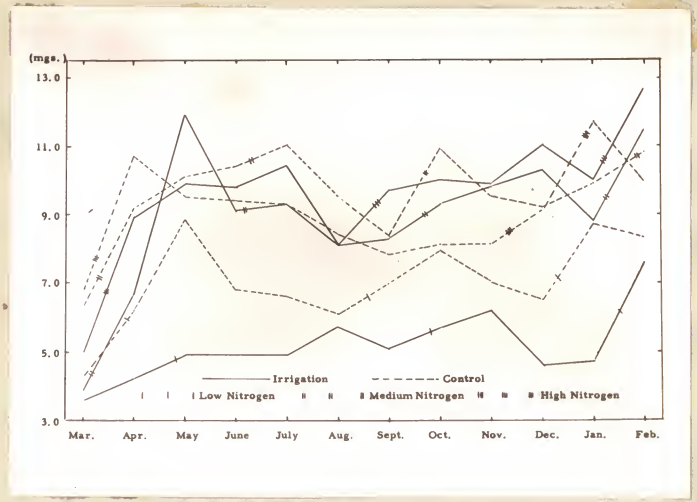


Figure 31. Seasonal changes in mean nitrogen content in milligrams of a satsuma leaf during the 1953-1954 season.

TABLE 41

Mean Nitrogen Content in Milligrams of an Average Hamlin Leaf as Affected by Varying Soil Moisture and Nitrogen Application Levels During the 1953-1954 Season

Month	Treatments						Average for Dates
	Field Capacity			Control			
	Nitrogen Level			Nitrogen Level			
	Low	Med.	High	Low	Med.	High	
March	3.2	3.8	3.9	3.2	4.0	3.2	3.6
April	3.5	4.3	4.3	3.6	4.7	4.0	4.1
May	4.0	4.7	4.6	4.8	5.1	4.7	4.7
June	4.0	4.1	5.1	3.3	4.9	4.4	4.3
July	3.2	5.3	5.6	4.2	6.1	4.7	4.9
August	2.9	4.5	5.2	3.6	5.6	4.7	4.4
September	3.1	4.3	5.2	4.4	4.5	4.2	4.3
October	4.0	4.4	5.3	4.4	4.9	5.3	4.7
November	4.1	4.6	5.1	4.7	5.9	4.8	4.9
December	4.3	4.5	5.4	4.0	4.2	5.2	4.6
January	3.5	4.5	5.2	5.2	4.6	5.4	4.7
February	3.8	5.6	5.2	4.4	5.5	4.9	4.9
Average for Treatments	3.6	4.6	5.0	4.2	5.0	4.6	

L. S. D. Between:	At 5% level	At 1% level
Treatment Means:	0.6 mg.	0.8 mg.
Nitrogen Means:	0.4 mg.	0.6 mg.

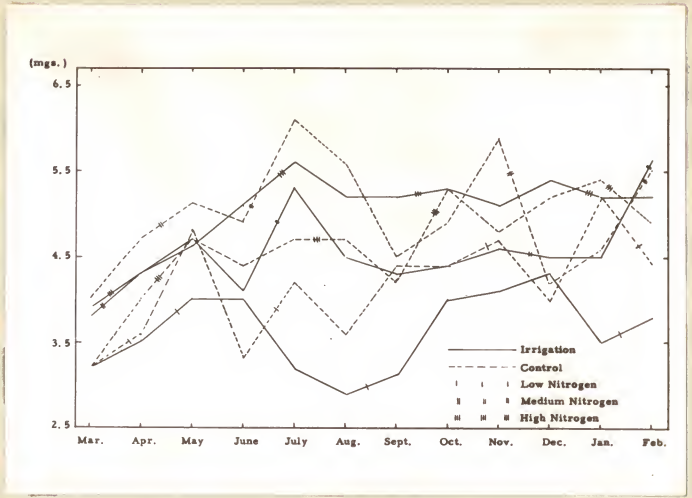


Figure 32. Seasonal changes in mean nitrogen content in milligrams of a Hamlin leaf during the 1953-1954 season.

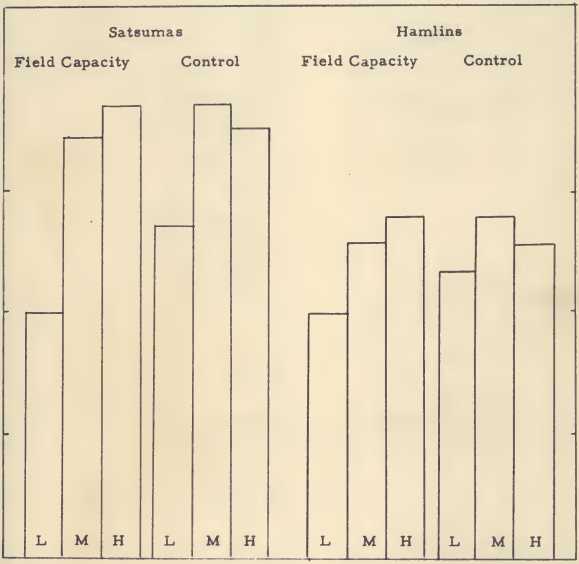


Figure 33. The relationship between nitrogen levels and the seasonal averages for nitrogen per leaf, 1953-1954 season.

L = Low nitrogen, M = Medium nitrogen, H = High nitrogen

differential nitrogen levels.

A study of the seasonal changes in mean nitrogen content of a leaf of each variety, presented graphically in Figures 31 and 32, revealed the existence of a general pattern in both varieties, with a minimum average in March and a maximum average in February. However, the maximum average for a Hamlin leaf was repeated three times in the second season while that of a satsuma leaf was reached only in February. Furthermore, the values for leaf nitrogen content in the satsumas under various treatments maintained almost the same relative positions throughout the season, while those of Hamlins were not consistently related to treatments.

A study of the relationship between the differential nitrogen levels and the relative mean nitrogen content of a leaf of both varieties is presented graphically in Figure 33. An evaluation of their curvilinear regression correlation indicates the presence of a highly significant correlation in both cases.

11. Shedding, dropping and splitting: The data on shedding of flowers, dropping of fruitlets, and splitting of fruits of Hamlin oranges and satsumas are presented in Tables 42 and 43. A summary of the analysis of variance of these data is given in Tables 17a and 18a of the Appendix.

In both varieties, flower shedding was not influenced by treatments. Dropping also, before the June drop, showed no response to the

TABLE 42

Numbers of Shed Flowers and Dropped Fruits of Satsuma as Affected by Varying Soil Moisture and Nitrogen Application Levels

Season	Type	Treatments						Average for Dates
		Field Capacity			Control			
		Nitrogen Level			Nitrogen Level			
		Low	Med.	High	Low	Med.	High	
1952-1953 Season	**Fruit Dropping 5-16-52	27	56	34	34	28	26	34
	11-1-52	34	57	73	30	45	41	47
	-1-	51	81	54	41	38	43	51
	Averages	37	65	54	35	37	37	
	Flower Shedding 3-21-53	5	37	30	24	121	3	37
	4- 4-54	19	41	20	35	64	65	41
		33	15	50	45	22	94	43
	Averages	19	31	33	35	69	54	
1953-1954 Season	Fruit Dropping 4-11-53	2	61	71	24	297	6	77
	5-16-53	47	148	27	165	42	196	104
	-2-	81	7	24	82	19	88	50
	Averages	43	72	41	90	119	97	
	*Fruit Dropping 5-23-53	00	16	8	17	22	6	12
	11-7-53	10	24	2	20	18	37	19
	-3-	20	4	16	15	24	32	19
	Averages	10	15	9	17	21	25	

	At 5% level	At 1% level
*L. S. D. for treatment effect	30	42
L. S. D. for irrigation effect	17	24
**L. S. D. for treatment effect	17	25
L. S. D. for irrigation effect	10	14

TABLE 43

Numbers of Shed Flowers, Dropped Fruits, and Split Fruit of Hamlin as Affected by Varying Soil Moisture and Nitrogen Application Levels

Season	Type	Treatments						Average for Dates
		Field Capacity			Control			
		Nitrogen Level			Nitrogen Level			
		Low	Med.	High	Low	Med.	High	
1952-1953 Season	Fruit Dropping	5	9	11	8	9	11	9
	5-16-52	3	5	14	10	8	12	9
	8- 9-52	9	4	7	11	6	9	8
	-1-							
	Averages	6	6	11	10	8	11	
	Fruit Splitting	47	40	106	53	91	56	66
	8-16-52	25	29	109	72	45	45	54
	11-1-52	75	89	109	62	77	57	78
	-1-							
	Averages	53	49	108	62	71	53	
1953-1954 Season	Flower Shedding	59	624	105	188	86	139	200
	2-21-53	166	387	40	31	89	132	141
	3-7-53	32	32	192	246	54	117	112
	Averages	86	348	112	155	76	129	
	Fruit Dropping	139	342	226	319	311	226	261
	3-14-53	422	252	288	245	238	160	268
	5-16-53	90	152	147	231	198	333	192
	-2-							
	Averages	217	249	220	265	249	240	
	Fruit Dropping	3	5	3	10	3	3	5
	5-23-53	5	3	6	8	1	8	5
	8- 1-53	1	3	0	4	2	13	4
	-3-							
	Averages	3	4	3	7	2	8	
	Fruit Splitting	137	86	62	163	96	61	101
	8-8-53	58	95	89	92	53	84	79
	11-7-53	49	56	65	69	37	37	52
	-2-							
	Averages	81	79	72	108	62	61	

treatments in either variety. During the first season, dropping of satsumas after the June drop was significantly lower in the irrigated plots than in the controls. However, during the second season the satsuma dropping, after the June drop, was significantly lower in the controls than in the irrigated plots. On the other hand, dropping after the June drop in both seasons for the Hamlins showed no relation to the treatments.

Splitting was not observed in satsumas, but in the Hamlins it started in the first half of August each season, and continued until the end of November. Treatments seemed to have no effect on the amount of splitting observed in either season.

V. DISCUSSION

Findings of fertilizer experiments with citrus trees, as well as with other fruit trees grown under certain conditions (119), could be conclusive only if the experiment was set up as a field trial. A factorial research arranged in a randomized block design was selected to study the significance of interaction between nitrogen application levels and irrigation.

Previous studies on hops (40), Marsh grapefruit (3), grapes (77), Valencia orange (124), and agronomic crop plants (112, 113, 114, 87, 109), indicated that periodic analysis of leaves of similar age and taken from a suitable position from plants receiving differential nitrogen fertilizers, reflects the physiological response of those plants to the differing fertilizers as far as nitrogen, phosphorus and potassium are concerned. Root analysis could be used very efficiently as an index for trees' response to sodium nutrition, but not for nitrogen (76).

Data for fresh weight of leaves of the 1952-1953 season failed to show any response to the treatments used because the trees were still under the effect of previous treatment. Determinations of the second season results, however, showed an increase attributed to the medium nitrogen levels as well as the high levels over that of the low levels, with and without irrigation. The amount of rainfall received by the trees in the second season (Table 1) masked the effect of irrigation.

The similarity between the responses of the medium and the high levels of nitrogen indicates that the medium levels were quite enough to bring out the utmost of the physiological processes of both varieties as far as fresh weight of leaves is concerned. The consistently larger value of the mean fresh weight of leaves of satsuma twigs than of the Hamlin twigs is mostly related to the varietal differences. It is interesting to note that the varietal characteristics affected the time of fresh weight minimum, this being in March for satsumas and in August for Hamlins. The maximum fresh weight of samples of both varieties was not attained at the same date, being in November for Hamlins and in February for satsumas. The March samplings of the two varieties were not alike in their ages, being less than a week old for satsumas and three weeks old for Hamlins. This explains why the minimum value of satsumas was found in March; but not why Hamlins had an August minimum. There seems to be no explanation for the Hamlins' behavior except factors of carbohydrate formation and transportation.

Results of the determination of dry weight of leaves during the second season were in agreement with the results for fresh weight. Previous studies on crop plants (47), barley (81), apples (48, 118), and Valencia oranges (107), indicated that an increase in the nitrogen level, within certain limits, induced a corresponding increase in the dry weight of the leaves. Neither the minimum nor the maximum value for average dry weight was found in the same month for Hamlins as for satsumas.

Maximum and minimum for satsumas were in the same months as indicated above for fresh weight, and so was the minimum for Hamlins; but the maximum dry weight of Hamlin leaves was reached in February, instead of November as for fresh weight. Again, the differing behavior of the two varieties is attributed to their different physiological activities for carbohydrate formation and transportation.

Study of the effect of the differential nitrogen levels and irrigation on the dry weight as percentage of fresh weight during the second season disclosed the presence of an increase of dry weight percentage of satsuma leaves associated with an increase in the nitrogen levels from low to medium, but not beyond that level, with or without irrigation (Table 12). Similar studies on the nutrition of tobacco (53) and sugar cane (36), indicated that an increase in nitrogen levels of the soil plots was accompanied by a decrease in dry weight percentages of their leaves. However, a previous study of young Valencia orange trees (107), along the same line of investigation, showed an increase in the dry weight percentage when the nitrogen levels of the fertilizer increased. Apparently field crop plants, with their short life cycle, are different from citrus trees as far as nitrogen uptake is concerned. Furthermore, leaf age showed its significance in the seasonal fluctuations of the percentage values of the two varieties. Both varieties attained their minimum values at the beginning of the season in March and their maximum values at the end of the season in February.

Obviously, the relative values of both moisture content and carbohydrates were responsible for such an outcome.

A new cell is characterized by its thin walls and its low carbohydrate content (5), together with a highly hydrated condition of protoplasm; all these factors combine to produce a low dry-weight percentage for a young leaf. As the season progresses, the cell forms thicker walls and accumulates larger amounts of carbohydrates and oils, while the free-water content of the protoplasm decreases. Obviously, the result would be an increase in the dry weight percentage, with different rates for different varieties because of the fundamental differences between varieties in the limits of their physiological processes.

Previous workers (5) have found that the dry matter of full-sized young citrus leaves ranged from about 29 to 45 per cent of the fresh weight. This agrees reasonably well with the findings here given, in which the range was from 29.64 to 40.49 per cent for satsuma leaves and from 27.91 to 34.76 per cent for Hamlin leaves of full size.

A slightly larger number of leaves was found on Hamlin twigs for both medium and high nitrogen applications, with and without irrigation, than on trees in the low nitrogen plots, during the second season. Satsumas have more leaves per twig than Hamlins, and even the low nitrogen application did not affect this. A small amount of available nitrogen seems adequate to bring out the full potentialities of the bud for developing leaves, and a smaller amount seems to suffice for this in

satsumas than in Hamlins. Perhaps the fact that the satsuma trees are much younger than the Hamlins enters into the situation.

A higher value of fresh weight for 30 disks of satsuma leaves was obtained under high levels of nitrogen, with or without irrigation, than with lower nitrogen applications. This is one of the few cases of significant difference between high and medium nitrogen levels. Irrigation gave higher values of leaf weight per unit area than did the control plot, for high nitrogen levels in satsumas. It is interesting to note that the maximum value was found in November, whereas the fresh weight of all leaves in a sample was maximum in February. This suggests that there was an increase during the winter in leaf area, together with a decrease in either water or stored food. Increase in fresh weight per unit area may mean increase in leaf thickness or it may mean increase in food storage and hydration. But such thickness could hardly be reversible. The seasonal pattern of the weight of 30 disks is mostly attributed to the differences in ratios between moisture and dry matter of the leaf, throughout the season. Unfortunately, there is no other work along this line reported in the literature.

Dry weight of sample and number of leaves of Hamlin varied significantly with nitrogen application, and it is surprising that dry weight per leaf does not. Dry weight of sample and dry weight per leaf in satsumas showed a similar response to the differential levels of nitrogen application. An increase in dry weight per sample of Hamlins,

accompanied by a corresponding increase in the number of leaves of the sample, will decrease the average weight per leaf. On the contrary, a similar increase in dry weight per sample of satsumas, without a corresponding increase in number of leaves per sample, would lead to an increase in the average dry weight per leaf. A study of the seasonal fluctuations of the average dry weight per leaf in both cases revealed a minimum in early spring and an increase in dry weight per leaf as the leaves aged. This is in accord with the findings of Smith and Reuther (106), for Valencia oranges. Apparently, such a seasonal trend is mainly attributable to the steady increase in size of leaf and in thickness of cell walls and storage of reserve food during the season.

Data for chlorophyll content of both seasons revealed a significant correlation between the nitrogen levels and chlorophyll content of leaves. Similar studies have been carried out on tobacco (53), sweet orange (94), rye (54), apple (64, 98), Elberta peach (66), and sour orange (28), and they are in full agreement with these findings. Chlorophyll content is greater in leaves of either satsumas or Hamlins than in those of Elberta peaches (66). This is probably due to the greater thickness of the citrus leaves; moreover, differences exist in climatic and soil conditions between New York state and Florida. However, the chlorophyll content of sour orange seedlings, as reported by Chen (28), is even lower than that reported for Elberta peaches. No obvious reason can be offered for this wide difference between citrus species

in chlorophyll content, since the same technique of chlorophyll determination was used.

Medium nitrogen levels induced almost as high values of chlorophyll content as high nitrogen, and significantly more than the low nitorgen plots; while irrigation failed, in three cases out of four, to induce any significant increase in chlorophyll content over that of the controls. A comparison between the studies of Elberta peach (66), sour orange (28), and these findings disclose an interesting difference. A maximum value for chlorophyll content of Elberta peach was attained in New York state in June, while those of the sour orange seedlings (28) and of the satsumas in this research were reached in October or November, and Hamlin leaves had maximum values in August and September. These differences seem to be related to the differing climatic conditions of the two states, besides the varietal characteristics. For both Hamlins and satsumas there is a strong tendency toward a decrease in chlorophyll content in the winter. Harris and Boynton (66) found such a decrease with leaf age for peaches under low nitrogen but not consistently for high nitrogen. The studies of Okuntsov on potato leaves (91) revealed that chlorophyll pigments undergo decomposition with age. Furthermore studies of Michael (85) on nasturtium leaves indicated that the chlorophyll decomposition of leaves is accompanied by protein decomposition. Perhaps the reason for such a destructive step for chlorophyll content is to build up more available nitrogen for the coming flush.

In both seasons and in both varieties (Hamlin and satsuma) a positive correlation was found between the nitrogen application levels and the nitrogen per cent of leaves on a dry weight basis. Similar studies with sweet orange seedlings (26) and cotton plants (121) grown in water cultures reported the same sort of correlation.

Three nitrogen applications were received each season by the trees involved in this experiment, in March, June, and November. There was no apparent effect of these applications on the nitrogen percentage of the leaves, as indicated by any rise immediately following them. In his investigation of the effect of fertilizers on Marsh grapefruit leaves, Hilgeman (69) found a rise in leaf nitrogen per cent following each application of nitrogen to the soil in summer, fall, and winter. Whether this difference is due to differences in nitrogen in the soil solution, to rootstock, to species, or to climatic factors cannot be determined on the basis of present evidence. The studies of Chapman and Parker (27), Wallace (125), and Roy et al. (102), on citrus nutrition in relation to timing, showed that nitrate uptake in citrus is independent of the activities of the top of the tree and depends, mainly, on the root temperature. It is a well-known fact that, in the spring, the surrounding atmosphere around the top of the tree is warmer than the soil temperature. Such a situation will increase the activities of tops earlier than those of roots. Further studies on nitrogen absorption by citrus, carried out by Winston et al. (127) led to the conclusion that "nitrogen application as

fertilizer does not necessarily mean its absorption and utilization by the plant."

Studies on the fertilization of sugar cane (134), barley, oats, and wheat (132), grapes (116), McIntosh apples (11), Winesap apples (126), and figs (99) have also shown a positive relationship between the nitrogen levels in the soils and the nitrogen per cent in the leaves. Studies on citrus fertilization in field plots made with grapefruit in Trinidad (65), and in Arizona (45), and on navel and Valencia oranges in South Africa (117), have further supported this conclusion.

Leaves of satsumas showed a maximum percentage of nitrogen in the young new leaves of the spring flush, followed by a steady decline throughout the season to a minimum the next February. Previous studies on the seasonal fluctuations of nitrogen percentage of Valencia orange in Florida (106, 107) and in California (130), of tung (41), and of Washington navel orange (129), have all showed a similar seasonal curve of decline in nitrogen per cent of leaves with age until midsummer. The Hamlin curve, however, did not show that decline. Instead, the nitrogen value was fairly constant until midsummer, with a decrease to a minimum in early fall and a later rise to a maximum value for most plots in January, followed by another minimum in February.

Studies by Winston and Parker on the Washington navel orange (129), disclosed the presence of a peak in the curve of the nitrogen percentage in September, followed by a steady decline until the end of leaf

life. Investigation on the Valencia orange by Cameron and Compton (21) showed an increasing trend of the nitrogen percentage values during summer and autumn to a midwinter maximum. Likewise, Hilgeman (69) found with Marsh grapefruit that there was a considerable increase in the nitrogen percentage of leaves during the summer, fall, and winter. These differing seasonal patterns for nitrogen percentage seem partly attributable to climatic conditions, and may also be varietal in basis. In all these studies, however, there is a trend toward an increase in nitrogen percentage of leaves in mid-winter, prior to the spring flush.

The trees, as previously mentioned, were supplied all the recommended minerals except nitrogen, which was added to the trees at different rates. No mineral deficiencies were noticed during the experiment, except for nitrogen in the trees grown under low nitrogen levels.

A comparison between the chlorophyll content of satsuma leaves in February and their nitrogen percentage, both being at low values, would imply that nitrogen may be re-utilized to some extent, as is reported for leaf potassium (6).

Increasing the rate of application of nitrogen to the soil from 0 to 3.5 lbs. per tree for satsumas and to 5.5 lbs. for Hamlins during the first season caused an increase in the leaf nitrogen from 2.37 per cent to only 3.23 for satsumas, and from 2.37 per cent to only 2.92

per cent for Hamlins (Tables 30 and 31, respectively). During the second season, the corresponding increase in the leaf nitrogen for satsumas was from 2.51 to 4.38 per cent, while that of Hamlins was only from 2.22 to 3.33 per cent (Tables 32 and 33, respectively). On a much wider range of nitrogen availability to roots of sweet orange seedlings, in nutrient cultures, Chapman and Liebig (26) found that increasing the nitrate level from 7 to 419 ppm increased the leaf nitrogen only from 3.21 to 3.67 per cent. Gregory (59) reported also for barley grown in nutrient solutions that there was no corresponding increase in leaf nitrogen with increases in available nitrates in the nutrient medium. There does not seem to be much luxury consumption of nitrogen, and maintaining the available soil nitrogen above a fairly low level seems to induce little or no increase in the nitrogen percentage of leaves. The increase in available nitrogen is reflected in increased formation of plant tissues, instead of being stored uselessly. In another words, the relationship between the concentration of nitrates in solution, or in the soil, and the nitrogen percentage of the leaves, on a dry weight basis, is curvilinear rather than linear. Similar results were reported by Von Dikow (40) in studies of hops, where increasing the fertilizer applications above a certain level failed to show a further increase in mineral content of leaves.

The total nitrogen content of the leaf samples showed the same relation to the levels of nitrogen application to the soil as did the fresh

and dry weights of these samples as the percentage of nitrogen in the leaves showed. As might be expected, however, the change in total nitrogen of the leaves during the season was quite different from the change in percentage of nitrogen. Whereas the nitrogen percentage was highest in the youngest leaves of satsumas and lowest in the oldest ones, the reverse was true of the total nitrogen content. It is evident that the decrease in nitrogen percentage during the season is not due to actual loss of nitrogen from the leaves, but only to the increase in carbohydrates, which is enough more rapid than the nitrogen increase to cause a decreasing percentage of nitrogen.

The total nitrogen content per leaf bears the same relation in satsumas to the nitrogen percentage as the total nitrogen content of the whole leaf samples. This is not the case with the Hamlin leaves. The nitrogen content per leaf follows the same course as in satsuma leaves, and increases steadily as the leaves grow older; but the total nitrogen per sample does not continue to increase throughout the season, although starting with a minimum value in March. It will be remembered that the percentage of nitrogen in Hamlin leaves also followed an irregular seasonal pattern, and was lower in midsummer than at the season's close. The difference between total nitrogen per leaf and total nitrogen per sample is due to the loss of some of the leaves making up the sample as the season progressed. The number of satsuma leaves per sample did not change with time. The number of Hamlin leaves

decreased slightly (Table 17) because of heavier scale infestation on these leaves than on the satsumas.

In total nitrogen per leaf, as well as in the total nitrogen per sample and in nitrogen as percentage of dry weight of leaves, the medium nitrogen applications induced a response as great as that of high nitrogen.

Because of the ease with which nitrates are leached from the light sandy soil used in these studies (120, 31, 110), it might have been expected that irrigation to maintain soil moisture constantly near field capacity would have caused more nitrogen deficiency than in the control plots. Rainfall often exceeded the 2.3 inches of water desired weekly, especially if it came immediately after an irrigation. Yet only in one instance is there any indication of such deficiency, where the control plots gave significantly higher values than the irrigated ones. That was in the chlorophyll content of satsuma leaves in the low and medium nitrogen plots. On the other hand, there was also only one case where the irrigated plot gave higher values than the non-irrigated one, and that was in the value for fresh weight per unit area of satsuma leaves in the high nitrogen plots. Otherwise there were no significant differences due to irrigation, suggesting that even in the control plots there was never any serious moisture deficiency.

Differential levels of nitrogen and irrigation failed--except for the case of dropping after the June drop in satsuma--to affect the shedding of flowers or the dropping of fruitlets of either Hamlin or satsuma.

In similar studies carried out in California, Coit and Hodgson (29) found that frequent irrigation would minimize the number of dropping fruitlets of Washington navel orange. However, Furr et al. (51), working with the same variety in California, reported that irrigation application could not stop those dropping spells, which were attributed mainly to harsh climatic conditions. Investigations with apples in New York (67) and Massachusetts (109), and with Marsh grapefruit in Arizona (84) indicated that nitrate applications at blooming succeeded in reducing the number of fruitlets which fell. On the other hand, similar studies carried out on apples (39) in Ontario, Valencia oranges (17) in California and Washington navel oranges in California (51) and South Africa (122), indicated that nitrate fertilizer has little to do with decreasing the amount of shedding or dropping, which is mainly the result of "spells of hot weather prior to each drop, accompanied by dry wind and low relative humidity" (122).

Dropping of satsumas after the June drop was affected by irrigation in both seasons, but in opposite directions, being decreased in 1952-1953, and increased in 1953-1954 seasons. The reason for that divergence is mostly attributed to the rainfall of the second season, which was greater than has been recorded for many years past. It is obvious that too much water is as harmful as too little water.

Splitting has not been observed in satsumas, and the number of splitting fruits of Hamlins was not affected by the differential treatments

in either season. Unfortunately, no other studies on splitting of citrus fruit have been found.

In most of the measurements of the 1952-1953 season, there was no response to the differential nitrogen treatments, while the response to them was significant in the 1953-1954 season. Apparently the difference in response of the two seasons was due to the effect of previous treatment. The question naturally arises of how long the investigator must wait in such research for the effect of previous treatment to be dissipated. The studies of Wagner (123) on grapes and Hilgeman et al. (70) on Marsh grapefruit in Arizona indicated that whenever the nitrogen per cent reached 1.24 and 2.35 in mature leaves of vines and Marsh grapefruit leaves, respectively, no significant response to nitrogen treatment was obtained. Furthermore, when the nitrogen content of Marsh grapefruit leaves was as low as 1.7 per cent, a very fast response was found. Apparently, from Tables 30, 31, 32, and 33, both maximum and minimum values of nitrogen per cent for both satsuma and Hamlin in Florida are larger than those of Marsh grapefruit in Arizona. No minimum value of leaf nitrogen was found in these studies below which applications of nitrogen to the soil gave increased values of leaf nitrogen and above which such applications were ineffective.

Obviously, the length of the transition period between the previous treatment and any similar nitrogen nutrition study depends on how long a time is required for the nitrogen level of the leaves to drop to a

minimum before starting the experiment. The consistency of response to increased nitrogen in the soil during the second season in these studies indicates that the previous fertilizer treatment was no longer a limiting factor after one year.

VI. SUMMARY AND CONCLUSIONS

Satsuma leaves are more numerous per shoot and heavier individually than Hamlin leaves. They also run higher in nitrogen and in chlorophyll contents than Hamlins. The dry weight of satsuma leaves constitutes a larger percentage of their fresh weight, and the fresh weight per unit area is greater, than in Hamlin leaves.

The response of the two varieties to differential applications of nitrogen to the soil were quite similar as judged by the fresh and dry weights of the leaves on an average shoot, by the chlorophyll content of the leaves (weight per unit area), and by the total and the percentage content of nitrogen in leaves. Significant differences were observed in the satsumas alone as indicated by the dry weight per leaf, and the weight of leaves as percentage of fresh weight; only in Hamlins did the number of leaves per shoot correlate with soil nitrogen applications.

When the responses of these species to three levels of soil nitrogen were analyzed, it was found that when any significant differences were observed in the leaf characters studied, the high nitrogen plots always gave higher values than the low nitrogen ones. Usually there was no significant difference between responses of the high and medium nitrogen plots.

The leaves of the spring flush only were studied, and monthly analyses made from March, when they first appeared, until February,

just prior to the next spring flush. For both Hamlins and satsumas the values for dry weight and nitrogen in an average leaf, and of dry weight as percentage of fresh weight of the leaf, were lowest in the young new leaves of March and increased to a maximum at the end of the period in February. The values of fresh and dry weights of the leaves on a single twig, and of the nitrogen in such a leaf sample, showed a similar seasonal trend for satsumas; but in the Hamlins these items did not follow any definite seasonal pattern.

The leaf nitrogen of satsumas as percentage of dry weight of the leaf had a seasonal curve just the reverse of that for nitrogen on an absolute basis, being highest in March and lowest the next February. The fresh weight of a given area of satsuma leaf was least in the young March leaves, but reached maximum value in November and declined thereafter somewhat. The seasonal trend of these items was not consistent in the Hamlins.

The chlorophyll content of satsuma leaves, determined as weight per unit area, was lowest in the young leaves of March, increased to a maximum in autumn, and decreased again to a second minimum in February. In Hamlin leaves the chlorophyll also had a midseason maximum, a couple of months earlier than in satsumas, and decreased somewhat thereafter, but there was neither the very low value shown by satsumas at the beginning of the season, nor as low an end-season value in February.

Maintaining some plots near the field capacity for water at all times by irrigation failed to give values for the measured quantities which were significantly different from those of the unirrigated control plots in most cases. Exceptions were the measurements of fresh weight per unit area in the high nitrogen plots, and of chlorophyll content in the low and medium nitrogen plots, both in the case of satsuma leaves only.

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VIII. APPENDIX

TABLE 1a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Total Fresh Weight of Satsuma and Hamlin Leaves in Two Seasons

Sources of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	24,704.7877	270.3001	4,934.4524	17.5356
Reps.	3	2	1,276.5230	14.4530*	1,248.1205**	1.0514
Treatments	5	5	977.0320	34.8801**	187.0310	1.4498
N.	2	2	242.5900	82.6442**	64.8410	3.3995*
I.	1	1	1,877.0910	2.4257	605.0570	0.1088
N. x I.	2	2	1,261.4500	3.3433	100.2190	0.1706
Error	14	10	1,142.1470	3.7529	150.3056	0.8184

TABLE 2a

Analysis of Variation: Pooled Analysis of Data for Both the Hamlins and the Satsumas, Second Season

Sources of Var.	D. F.	Tot. Sum of Squares	Mean Squares	"F" Value
Variety	1	596.0805	596.0805	235.5863**
Nitrogen	2	130.2803	65.1402	25.7451**
Irrigation	1	0.9241	0.9241	0.3652
N. x I.	2	2.6755	1.3378	0.5287
N. x Var.	2	41.8071	20.9036	8.2616**
I. x Var.	1	1.6104	1.6104	0.6365
N. x V. x I.	2	3.3523	1.6762	0.6625
Error	24	60.7243	2.5302	

TABLE 3a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Total Dry Weight of Satsuma and Hamlin Leaves in Two Seasons

Sources of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	3,993.3734	42.3586	829.8025	2.7370
Reps.	3	2	168.5957	2.7514*	140.4828	0.1217
Treatments	5	5	168.7550	5.2473**	25.6779	0.2838
N.	2	2	13.4705	12.7056**	23.3891	0.6182*
I.	1	1	402.6118	0.1667	45.7286	0.0264
N. x I.	2	2	207.1111	0.3291	17.9413	0.0780
Error	14	10	188.8437	0.5620	42.0448	0.1075

TABLE 4a

Analysis of Variation: Pooled Analysis of Data on Dry Weight of Leaves for Both Hamlins and Satsumas, 1953-1954 Season

Sources of Var.	D. F.	Tot. Sum of Squares	Mean Squares	"F" Value
Variety	1	86.6852	86.6852	232.6495**
Nitrogen	2	20.4592	10.2296	27.4546**
Irrigation	1	0.0408	0.0408	0.1095
N. x I.	2	0.2909	0.1455	0.3905
N. x Var.	2	5.9885	2.9943	8.0362**
I. x Var.	1	0.1523	0.1523	0.4087
N. x V. x I.	2	0.7235	0.3618	0.9710
Error	24	8.9428	0.3726	

TABLE 5a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Dry Weight Percentage of Satsuma and Hamlin Leaves in Two Seasons

Sources of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	2,048.4200	22.5067	886.700	17.0194
Reps.	3	2	530.0133**	1.6228	3.1325	0.2435
Treatments	5	5	43.7840	1.9199*	71.1904	1.3360
N.	2	2	34.5950	3.7551**	136.1110	2.4915
I.	1	1	62.7300	1.9665	0.9800	0.0480
N. x I.	2	2	43.5000	0.0614	41.3750	0.8246
Error	14	10	22.8900	0.5742	52.4483	0.9852

TABLE 6a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Number of Leaves per Sample of the Hamlin and Satsuma in Two Seasons

Sources of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	28,573.9600	161.3333	14,976.0000	37.1112
Reps.	3	2	2,454.4870	5.4444	1,326.0000	1.0556
Treatments	5	5	1,139.1420	14.2667	839.2000	4.2222
N.	2	2	2,560.0400	10.0417	746.0000	9.5556*
I.	1	1	330.0430	0.1666	502.0000	0.8889
N. x I.	2	2	122.7940	25.5417*	1,101.0000	0.5556
Error	14	10	1,108.1990	5.2619	812.8000	1.3889

TABLE 7a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Fresh Weight of Thirty Disks of Satsuma and Hamlin Leaves in Two Seasons

Sources of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	12.9200	0.03365	2.4966	0.01003
Reps.	3	2	0.7960	0.00419**	0.5255**	0.00015
Treatments	5	5	0.8064	0.00269**	0.1573	0.00021
N.	2	2	0.7555	0.00386**	0.1423	0.00041
I.	1	1	1.0923	0.00375*	0.3121	0.00014
N. x I.	2	2	0.7145	0.00099	0.0949	0.00004
Error	14	10	0.4663	0.00054	0.0659	0.00087

TABLE 8a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Dry Weight per Leaf of Satsumas and Hamlins in Two Seasons

Sources of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	4,207,699.00	76,530.959	580,534.00	3,300.500
Reps.	3	2	159,690.66	3,500.930	105,025.00*	175.165
Treatments	5	5	142,691.80	8,389.249**	29,046.00	221.432
N.	2	2	52,504.00	17,285.160**	10,597.00	264.667
I.	1	1	198,199.00	828.375	99,012.00	0.500
N. x I.	2	2	205,126.00	3,273.770	12,512.50	288.664
Error	14	10	215,369.14	1,720.138	22,525.40	184.301

TABLE 9a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Chlorophyll Content of Thirty Disks of Satsuma and Hamlin Leaves in Two Seasons

Sources of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	739.5896	17.7400	171.3390	152.5336
Reps.	3	2	7.0283	0.2430	25.0201*	0.9142
Treatments	5	5	64.6434	3.0740**	15.9515*	26.0284**
N.	2	2	119.0205	6.7400**	37.7705**	64.8363**
I.	1	1	67.6704	1.5500**	2.0447	0.4356
N. x I.	2	2	8.7529	0.1700	1.0860	0.0169
Error	14	10	28.1963	0.1171	4.1541	2.0563

TABLE 9b

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Chlorophyll Content of Thirty Disks of Satsuma and Hamlin Leaves in Two Seasons
Sub-Plots

Sources of Variation	D. F.			Mean Squares			
	1952-1953 Season	1953-1954 Season		Satsumas		Hamlins	
		Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	144	196	198	412.7267	2,075.0918	348.0245	1,216.9008
Time	8	11	11	34.6360**	175.3868**	28.5575**	103.7060**
T. x I.	8	11	11	2.0030	1.1737	0.7351	0.4171
T. x N.	16	22	22	1.8187*	2.1424**	1.0895	0.6262*
T. x N. x I.	16	222	22	0.4653	0.5039	0.8358	0.4331
Error	96	130	132	0.8653	0.5747	0.8633	0.3655

TABLE 10a

Analysis of Variation: Pooled Analysis of Data on Chlorophyll Content of Satsuma and Hamlin Leaves in Two Seasons

Sources of Variation	D. F.	Mean Squares	
		1952-1953 Season	1953-1954 Season
Variety	1	179.8840**	25.3060**
Nitrogen	2	365.9350**	71.5690**
Irrigation	1	81.4830**	1.0400
I. x N.	2	14.7345	0.0007
N. x V.	2	85.1125**	0.0080
I. x V.	1	4.5896	0.9460
N. x V. x I.	2	11.6990	0.1829
Error	24	16.6382	0.9251

TABLE 11a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Nitrogen Percentage of Leaves of Satsumas and Hamlins in Two Seasons
Main-Plots

Sources of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	80.1794	1.2328	2.4256	19.0812
Reps.	3	2	4.4496	0.0059	0.3878*	0.4889
Treatments	5	5	9.4852**	0.2007**	0.1965	1.5463*
N.	2	2	22.1717**	0.4166**	0.3762*	3.3551**
I.	1	1	1.5759	0.1684**	0.0579	0.8326
N. x I.	2	2	0.7535	0.0010	0.0861	0.0944
Error	14	10	1.3854	0.0151	0.0668	0.3461

TABLE 11b

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Nitrogen Percentage of Leaves of Satsumas and Hamlins in Two Seasons
Sub-Plots

Sources of Variation	D. F.			Mean Squares			
	1952-1953	1953-1954		Satsumas		Hamlins	
	Season	Season Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	144	196	198	5.8814	33.3617	5.3150	6.9114
Time	8	11	11	0.2239**	2.5389**	0.1625**	0.1533**
T. x I.	8	11	11	0.0507	0.0598*	0.0548	0.0405
T. x N.	16	22	22	0.0528*	0.0287	0.0121	0.0358
T. x N. x I.	16	22	22	0.0160	0.0275	0.0157	0.0168
Error	96	130	132	0.0269	0.0272	0.0326	0.0274

TABLE 12a

Analysis of Variation: Pooled Analysis of Data on Nitrogen Percentage of Satsuma and Hamlin Leaves in Two Seasons

Sources of Variation	D. F.	Mean Squares	
		1952-1953 Season	1953-1954 Season
Variety	1	3.9097	1.0693**
Nitrogen	2	21.8704**	3.7570**
Irrigation	1	2.0196	0.9908**
I. x N.	2	0.1222	0.0847
N. x V.	2	3.6870*	0.0152
I. x V.	1	0.0765	0.0102
N. x V. x I.	2	1.4063	0.0107
Error	24	1.0585	0.1530

TABLE 13a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Total Nitrogen Content per Sample of Satsuma and Hamlin Leaves in Two Seasons

Sources of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	3,569,382.00	57,187.3340	700,884.00	3,880.940
Reps.	3	2	143,016.00	2,675.7780*	52,405.00	75.055
Treatments	5	5	201,893.00	8,391.9668**	35,405.20	634,054**
N.	2	2	188,504.00	19,831.2920**	39,186.50	1,477.555**
I.	1	1	454,851.00	1,568.1670	58,939.00	6.720
N. x I.	2	2	88,803.00	364.5415	19,857.00	104.220
Error	14	10	152,205.00	514.2976	41,904.80	56.056

TABLE 14a

Analysis of Variation: Pooled Analysis of Data on Total Nitrogen Content per Sample of Satsuma and Hamlin Leaves in the 1953-1954 Season

Sources of Var.	D. F.	Sum of Squares	Mean Squares	"F" Value
Variety	1	91,099.62	91,099.62	281.7247**
Nitrogen	2	34,629.83	17,314.92	53.5462**
Irrigation	1	1,000.66	1,000.66	3.0945
N. x I.	2	194.84	97.42	
N. x V.	2	7,987.87	3,993.94	12.3512**
I. x V.	1	574.23	574.23	1.7758
N. x V. x I.	2	742.68	371.34	1.1484
Error	24	7,760.73	323.36	

TABLE 15a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Nitrogen Content per Leaf of Satsumas and Hamlins in Two Seasons

Source of Variation	D. F.		Mean Squares			
			Satsumas		Hamlins	
	Sat.	Ham.	1952-1953 Season	1953-1954 Season	1952-1953 Season	1953-1954 Season
Total	22	17	3,942.960	96.6196	8.5410	5.2650
Reps.	3	2	213.720	3.3571	0.8900	0.0615
Treatments	5	5	251.302	13.0474**	0.4658	0.8223**
N.	2	2	461.938	28.6305**	0.3635	1.6267**
I.	1	1	243.844	3.7604	1.3890	0.1606
N. x I.	2	2	44.396	2.1079	0.1065	0.3489
Error	14	10	146.092	1.5222	0.4428	0.1030

TABLE 16a

Analysis of Variation: Pooled Analysis of Data on Nitrogen Content per Leaf of Satsumas and Hamlins in the 1953-1954 Season

Sources of Var.	D. F.	Sum of Squares	Mean Squares	"F" Value
Variety	1	148.2002	148.2002	159.2010**
Nitrogen	2	47.6234	23.8117	25.5792**
Irrigation	1	2.9867	2.9867	3.2084
N. x I.	2	4.1890	2.0945	2.2500
N. x V.	2	12.8908	6.4454	6.9238**
I. x V.	1	0.9343	0.9343	1.0037
N. x V. x I.	2	0.725	0.3625	0.3894
Error	24	22.3415	0.9309	

TABLE 17a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Number of Shed Flowers and Dropped Fruit of Satsumas in Two Seasons

Sources of Variation	D. F.	Mean Squares			
		1952-1953 Season	1953-1954 Season		
		Fruit Dropping -1-	Flower Shedding	Fruit Dropping -2-	Fruit Dropping -3-
Total	17	4,092.9444	15,626.5000	104,972.9445	1,694.5000
Reps.	2	472.7222*	64.5000	4,374.2223	65.3300
Treatments	5	449.2555	979.0333	2,901.1222	121.5660
N.	2	328.2222	860.1667	1,563.7223	30.1700
I.	1	1,104.4999**	2,762.7222	11,300.0555	460.0500*
N. I.	2	242.6667	206.0556	39.0556	43.7250
Error	10	90.1222	1,060.2333	8,171.8889	89.0670

	At 5% level	At 1% level
L. S. D. for Treatment Effect of Fruit Dropping (1)	17	25
L. S. D. for Irrigation Effect of Fruit Dropping (1)	10	14
L. S. D. for Treatment Effect of Fruit Dropping (3)	30	42
L. S. D. for Irrigation Effect of Fruit Dropping (3)	17	24

TABLE 18a

Analysis of Variation: Effect of Differential Nitrogen Levels and Irrigation on Numbers of Shed Flowers, Dropped Fruit and Split Fruit of Hamlin Oranges in Two Seasons

Sources of Variation	D. F.	Mean Squares					
		First Season		Second Season			
		Fruit Dropping -1-	Fruit Splitting -1-	Flower Shedding	Fruit Dropping -2-	Fruit Dropping -3-	Fruit Splitting -2-
Total	17	148.30	12,015.0	376,486.9445	123,666.945	194.50	17,271.50**
Reps.	2	2.40	865.0	12,086.2223	10,489.573	2.65	3,560.67
Treatments	5	15.40	1,468.2*	30,301.1221	1,018.189	19.03	900.23
N.	2	24.40	988.8	16,714.3888	2,289.389	12.67	1,604.17
I.	1	16.10	280.1	17,112.4995	537.056	29.39	1.39
N. x I.	2	6.05	2,541.7**	50,482.1667	863.723	20.23	845.73
Error	10	7.13	294.4	20,080.8890	9,759.686	9.40	564.90

No significant difference between either nitrogen or irrigation averages.

BIOGRAPHY

Ahmed Mohamed Labib El-Tomi was born on March 16, 1914, in Cairo, Egypt. After he had finished his high school education in Tewfikia Secondary School, he enrolled in the College of Agriculture, Cairo University, in September, 1933. There he spent four years, receiving the Bachelor of Science (Hon.) in Agriculture on June 2, 1937.

Following his graduation, he was appointed a teacher of Horticulture in the Intermediate School of Agriculture by the Egyptian Ministry of Education and served from October, 1937 until October, 1941.

From October, 1941 until October, 1947, the author was a teacher of Horticulture in the School of Agriculture in Bagdad, Iraq. In October, 1947, he returned to Egypt as Lecturer in Horticulture at Ibrahim University, Cairo, Egypt, where he also began work toward the Master of Science in Horticulture. This degree was awarded him in March, 1950 by Cairo University.

He came to the United States of America in August, 1951, for further graduate work in Horticulture. Since that time he has pursued studies in the University of Florida leading to the degree of Doctor of Philosophy.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of the committee. It was submitted to the Dean of the College of Agriculture and to the Graduate Council and was approved as partial fulfilment of the requirements for the degree of Doctor of Philosophy.

August 9, 1954

C. V. Noble
Dean, College of Agriculture

Dean, Graduate School

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